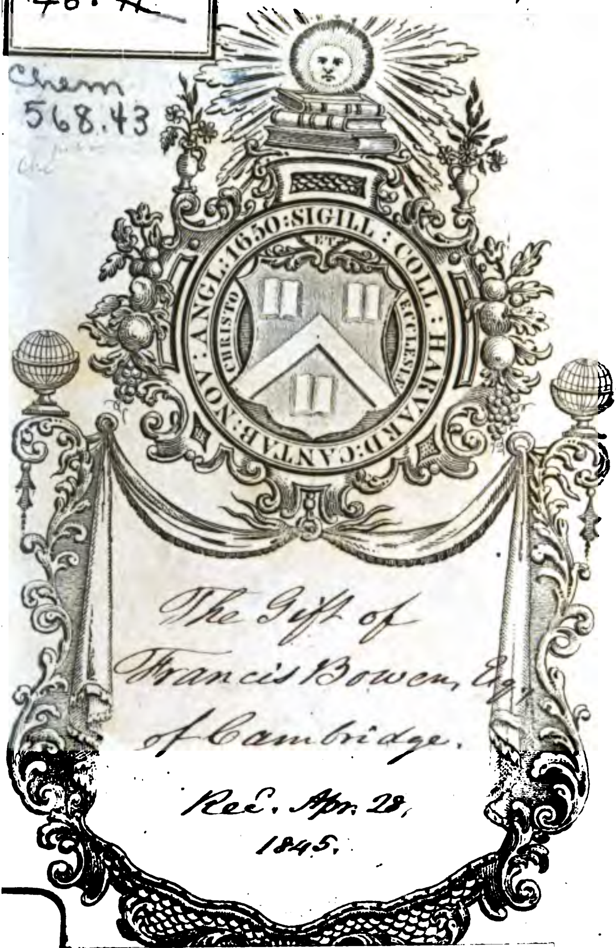
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CHRISTO ET ECCLESIAE

Editor of
N. A. Review
with respect
of Publisher

A
MUCK MANUAL,
FOR
FARMERS.

BY SAMUEL L. DANA.

"It is usual to help the ground with muck, and likewise to recomfort with muck, put to the roots; but to water it with muck-water, which is like to be more forcible, is not practised."—BACON.

SECOND EDITION, WITH ADDITIONS.

LOWELL:
BIXBY AND WHITING.
1843.

W. SCHOULER, PRINTER.

TO THE

CITIZENS OF LOWELL,

THESE PAGES, THE PITH OF EIGHT LECTURES ON THE

CHEMISTRY OF SOIL AND MANURE,

DELIVERED BY THEIR REQUEST,

ARE RESPECTFULLY INSCRIBED

BY THE AUTHOR.

LOWELL, JAN. 1, 1842.

PREFACE TO THE SECOND EDITION.

The dedication prefixed to this volume, shows its origin and object. By an accidental correspondence with Professor Hitchcock, the Geological Surveyor of Massachusetts, the Author unexpectedly found himself placed before the public, as an agricultural chemist. He had no intention of pursuing inquiries relating to agriculture, other than those arising from his researches, on the action of cow dung in calico dyeing. Attached as chemist, to the largest establishment of that art in our country,—daily, almost hourly employed in duties connected with it, he carried forward inquiries bearing upon practical farming, in answer only, to the many questions asked him by various persons, especially by Professor Hitchcock, and Mr. Colman, the Agricultural Commissioner of Massachusetts. Their published remarks induced some of the most active and intelligent of his fellow citizens to request of him a course of lectures on Agriculture, in the winter of 1839—40. Perfectly unexpected as was this request, it was acceded to with great diffidence. Whatever ideas the Author may have had on this subject, they assumed no systematic shape till this application, and then the lectures were prepared as they were weekly delivered. The Author's agricultural reading had been very limited, and that confined chiefly to the chemistry of farming.

Perhaps this was no serious loss to his hearers, as the lectures were expected to embody chiefly, the Author's peculiar views. This circumstance is alluded to, only to explain the reasons why so few references are made, by name to others. The statements were made from memory, from general impressions, called up during the act of preparing the notes for the lectures. Repeatedly urged, the Author reluctantly consented to their publication. Throwing off all the dress of a lecturer, and omitting the many details and illustrations, befitting the lecture room, the manuscript notes were thrown into paragraphs.—While the main drift of the whole was preserved, that the volume might not exceed a readable size, it was condensed, perhaps "even to a fault." The amount of this condensation, may appear from the fact, that nearly one-third of the whole course, has here been compressed into about thirty pages. In preparing the notes for the press, the Author often found it impossible to put his finger upon the passages of all the writers, whose opinions, he may have introduced. References to names have been generally omitted, except where the freshness of the results, entitled the authors to the humble tribute which such mention could confer. It is hoped that no injustice has been done, by omitting the name of those, whose ideas are embodied in these pages; ideas which have been so long before the world, that they have become almost common property.

The remarks relating to the geographical distribution of plants, are drawn up from a paper by De Candolle, published in one of the English journals, from the Bibliotheqne universelle de Geneva. In the chapter on the physical properties of soil, the Author has derived valuable assistance from a paper by Professor Schubler, of Tubingen, published in the journal of the Royal Agricultural Society of England.

Some of the principles of Agricultural chemistry laid down by the Author in this volume, especially the 1st, 2d and 3d, have been thought to be too broad by some persons, especially by a writer in the American Journal of Science, for whose opinion is felt all that profound respect, which exalted science and candor command. Upon a careful review of these principles, it seems to the Author that they are true as general expressions of facts. They may not be more limited and guarded than they already are, without destroying their force. Less limited than they are would remove them farther from truth. It was hoped before a second edition should be called for, that the analysis undertaken by the writer, of the soil of pine barrens, to ascertain its quantity of alkali, would have been finished. The first edition of the following work having been wholly exhausted within six months from its publication, and large orders remaining unsupplied, a new edition goes to press, with fewer additions and improvements than the Author intended. It may be observed that this edition is enlarged, it is hoped, enriched, by several pages of new matter. Among the principal additions are several articles on manures, and a sketch of the celebrated Mulder's researches on geine, which will be found in the appendix to the fourth chapter. The whole has been carefully revised; a few unimportant errors have been discovered and corrected; a fuller table of contents, and a copious index—the last, prepared by the kindness of the Author's ingenious young friend, Mr. Samuel Webber Jr., are added.

The author would here publicly express his thanks to the editors of the various scientific and literary journals, who have inserted notices of his work, in their various publications. He feels under great obligations to the editors of the different agricultural newspapers, for the favorable opinion, they have, as far as the Author knows, uni-

versally expressed of this volume. Coming from all parts of the country, unsolicited, and from writers personally unknown to the author, he deems their opinion the best index of the value placed upon his humble labors by the agricultural community. S. L. D.

LOWELL, OCT. 1842.

CONTENTS.

CHAPTER I.

GEOLOGY OF SOIL.

1. Agricultural Chemistry aims to explain all the actions of earth, air, and water, upon plants. It refers to all their chemical relations, to the geology, mineralogy and chemistry of soil.

2. Agricultural geology explains the relations which soil bears to plants, and the manner in which that affects vegetation.

3. Agricultural geology confines itself to facts. It digs into the earth, observes what composes that; how its components act upon plants. Conversant only with facts, or logical deductions from these, it leaves to geology proper, the vast mass of observations, supported by the highest modern science, which teaches the origin, mode of formation, original condition, and successive changes which our globe has undergone.

4. The terms, primitive and secondary, used by geologists, are almost parts of common language; yet, need to be explained to the farmer.

5. Large tracts of all extensive countries are composed of rocks of a granite texture. This needs no definition. Such rocks having been observed to underlay all others, in the scale of rocks composing the earth's crust, were called primary. It was supposed that these were first formed. Out

of the ruins of these, no matter when or how ruined, other rocks have been made, called secondary. The ruins of the primitive rocks have been transported by water, and then gradually deposited layer upon layer. Under immense pressure, these layers of mud, sand, fine gravel, rolled stones, &c., have been hardened into solid rock; forming sandstones, slates, or even rocks presenting the crystaline structure, or texture of granite, by the action of heat, which the facts of modern geology teach, exists in the interior of our globe.

6. This internal heat is supposed to be the cause of volcanoes, and the primitive rocks themselves, to have been the ejection, under circumstances unknown, of the melted mass of the globe; ejections, similar in kind, to those of modern lava, but greater in degree.

7. Intermediate between modern lava, and primitive rocks, and actually passing into either, is a large class of ancient volcanic rocks, called trappean; such are basalt, trap, and highly crystalline porphyry.

8. However named and classed are the rocks of the earth's surface, they have one common origin, the molten matter of the globe. Hence, having a common origin, their ultimate chemical constituents are similar. If granitic rocks have a certain chemical constitution, then sandstone, slate, &c., having been formed from worn out and worn down granitic rocks, have a constitution chemically like them.

9. To the agriculturist, the terms *primary* and *secondary*, are useless. Equally so are all distinctions of soil based on these terms.

10. Soil is the loose material covering rocks, and often is included in that term. It is supposed to have been formed from decayed rocks. Both are

to be classed by their origin. The origin of rocks refers not only to the mode of their first formation, but to their subsequent arrangement. The origin of all rocks, geology teaches, is from the molten matter of the globe. These have been, afterwards, in some cases, removed by water, and in part remodified by heat (5). Referring rocks to their origin, they are divisible into two great classes.

1st. Those formed by fire.

2d. Those formed by water.

11. This division relates both to the origin and distribution. In their origin all rocks are truly *igneous* or by fire. In their distribution they are *aqueous* or by water. This is the only division necessary to the farmer. It is the division taught and demanded by Agricultural Geology.

12. The first class includes all the highly crystalline rocks, granite, gneiss, sienite, greenstone, porphyry ; it includes also, basalt, lava, volcanic sand. The products of volcanoes, whether ancient or modern, agricultural geology places in the same class, including thus all that portion which forms the largest part of the earth's surface.

13. The second class includes sand, clay, gravel, rounded and rolled stones of all sizes, puddingstone, conglomerates, sandstones, slates. When these various substances are examined, a large part of sand is found to be composed essentially of the ingredients of the igneous rocks. This is true also, of sandstone, slate, of conglomerates, of bowlders.

14. There is a large deposit, or formation in some districts, composed almost wholly of one of the chemical constituents of the igneous rocks, united to air. The constituent is lime, the air is carbonic acid, forming by their union, carbonate of lime. Marble, limestone, chalk, belong to this formation.

These are not to be ranked as original igneous products, subsequently distributed by water. The lime, originally a part of igneous rocks, has been separated and combined with air, by animals or plants, by a living process, called secretion. The modern production of carbonate of lime, is still going on under the forms of shells and corals. Though belonging to neither division, the subject will be simplified by referring limestone to the second class of rocks; but it is truly a salt, and it will be discussed hereafter.

15. The chemical constitution of all rocks is similar. If rocks are divided into two classes, the first composed of those usually called primary, such as granite, gneiss, mica slate, porphyry; and the second class, composed of rocks, usually called trappean, as basalt, greenstone, trap, then the great difference in their chemical constitution is this:

The first, or granitic class, contains about 20 per cent. more of silex, and from 3 to 7 per cent. less of lime and magnesia and iron, than the second or trappean class.

16. If the language of geology is borrowed, and rocks which present the appearance of layers, or a "stratified structure," are divided into two classes, fossiliferous and non-fossiliferous, or those which do, or do not contain remains of animals or plants, it will be found that the fossiliferous are neither granitic nor trappean, yet are they to be classed with the last, agreeing with them, in containing less silica, and more lime, magnesia, and alumina.

17. The stratified non-fossiliferous rocks agree in chemical composition with the granitic, and the fossiliferous with the trappean and volcanic.

18. The trappean and fossiliferous contain the most lime and magnesia; the granitic and non-fos-

siliferous, the most silex. The great difference in chemical composition, between the two classes, is produced by lime and magnesia,—two substances, which, more than all others, have been thought to influence the character of soil.

19. The amount of this difference is about from 4 to 7 per cent.; yet notwithstanding this, the general chemical constitution of all rocks approaches so nearly to identity, that this may be laid down as the first principle in agricultural chemistry, that there is ONE ROCK, CONSEQUENTLY ONE SOIL.

20. To the farmer, all soil is primary. The question then arises, how do rocks and soil affect vegetation? As a consequence of the first proposition, it may be laid down as the second principle of agricultural chemistry, ROCKS DO NOT AFFECT THE VEGETATION WHICH COVERS THEM.

21. This is opposed to the geological doctrine of the times, and may seem to be opposed to the statement in section 18. The difference there stated, may be thought to produce corresponding effects in vegetation. This would be true if rocks exerted any influence on soils, due to their chemical constitution. A survey of the geographical distribution of plants, used for food, will show that the common doctrine of the chemical influence of rocks on vegetation, is not so well supported, as to be considered an established principle. It is not intended to deny that rocks do, by their physical constitution, affect vegetation. Unless it is shown that their physical depends upon their chemical constitution, the principle must be admitted as a general truth.

22. The plants used for food are cultivated on every variety of rock foundation which the earth presents. Their cultivation is limited neither by

granitic nor trappean, by fossiliferous nor non-fossiliferous rocks. Their product varies not more on different, than on the same geological formation. Every where, over every variety of rock, the cultivation of the food-bearing plants, repays the labor of the farmer.

23. Surveying Massachusetts, it is evident the grain crops are not influenced by the peculiar rock formations over which they are grown; for in this State, with the exception of modern volcanic rocks, all the various formations which the earth presents, are found. Yet no difference in the quality and quantity of crops of rye, oats, barley, wheat, Indian corn, is found, which can be attributed to different geological tracts.

24. All plants have a natural limit, a peculiar region, in which, unaided by the human race, they flourish and spread spontaneously. The smaller the limit of this natural boundary, the more difficult is the cultivation of the plant. Yet we find that the natural boundary is passed, and so plants come to live in an artificial region. There is a natural, and there is an artificial "habitat," or region; and this last is either horticultural, or agricultural. The first is unlimited, the second is limited by the great external circumstances of temperature and moisture.

25. The extreme north and south limits, which bound the cultivation of the food-bearing plants, are determined wholly by physical, physiological and social causes. Temperature is the great agent, which limits the agricultural "habitat" of the grain-bearing plants.

26. The distribution of plants is governed by the two following laws:

1st. The polar agricultural limits are bounded by lines passing through places of equal summer heat.

2d. The equatorial limits, by lines of equal winter heat.

These lines are called respectively, isotheral, and isochimenal. They by no means coincide. They often cut each other at right angles, and generally, from about 45 degrees north latitude,—they are parallel neither to one another, nor to the latitude. They are often highly curved.

And now for the proof of these general laws. Beginning with barley, the grass or grain which has been cultivated the farthest north; its fields are found in the extremity of Scotland, in the Orkneys and Shetland Isles, 61 degrees N.; in the Feroe Islands, between 61 and 62 1-2 degrees N.; in Western Lapland, near North Cape, in latitude 70 degrees; on the borders of the White Sea, in Western Russia, between 67 and 68 degrees, and near to Archangel, in Eastern Russia, about 66 degrees, in Central Siberia, the limit of barley is between 58 and 59 degrees N. There are no extended observations of the temperature of the northern portions of our own continent, and therefore the limit of barley in Northern America is left undefined. But its European line will probably define that which will limit grain cultivation in America.

Tracing a line through the points above named, it is the northern boundary of all the cereals, or grains. A little beyond this line is the boundary of the potato, and the belt between the two, is remarkable. It is the zone between agriculture, and fishing, and hunting, between races of men, subsisting on animal, and on vegetable diet, and those whose chief food is animal. The northern cultivation of barley is bounded, if its course is traced, by a very curved line. Is this determined by geological causes, or do causes purely physical erect a barrier

to its farther northward advance? The answer will be found, in tracing the temperature of the seasons of the different places, through which the limit of the northern cultivation of barley passes. It will be evident that the line of this limit is isotheral, for the mean temperature, Fahrenheit, is as follows:

	Latitude.	Year.	Winter.	Summer.
Feroe Isles,	61—62°	+45°	+39°	+51°
W. Lapland,	70	+33·8	+21·2	+46·2
Russia, at the mouth of the White Sea,	66—68°	+32	+10·2—8·8	+46·3

Casting the eye on this table, it is evident that the annual and the winter temperature have little influence on the barley limit, and that a mean summer temperature from 46 to 47 is the only indispensable physical condition, to the cultivation of barley. On the Atlantic islands, a mean temperature from 3 to 4 degrees higher is necessary, which compensates for excessive humidity. It is remarkable, that all the cereals have failed in Iceland, though its mean temperature is above that necessary for barley. Nor is this owing to its geological structure. In that, it agrees with the fertile shores of the Mediterranean. It is volcanic. So far as nitrogen, and carbonic acid, and ammonia, may be supposed to be evolved from the earth, and to contribute to the growth of grain, Iceland should equal fertile Italy. But such is not the fact, and it goes to prove that rocks affect very little the crops grown over them, even when the great physical element, temperature, is as high as is necessary. That grains fail in Iceland, is due to the excessively tempestuous rains with which that country is visit-

ed. If then, the limits of barley are defined by an isotheral line of 46 1-2 degrees in Europe, that will also limit its cultivation in America. So far as observation has extended, this is true, and the line of boundary is equally curved, and winding. If a similar table for the limits of wheat is constructed, by drawing a line through the most northern places, where this grain has been cultivated, the physical conditions, essential to its cultivation, will be found as follows:

Mean temperature, Fahrenheit, of the

	Latitude.	Year.	Summer.	Winter.
Scotland, (Inverness)	58°	+46·3	+57·3	+36·5
Norway, (Drontheim)	64°	+39·5	+59	+23·5
Sweden,	62°	+39·5	+59	+23·5
St. Petersburgh,	60·25	+38	+60·8	+15·6

North latitude 64 degrees, appears then, to be the utmost limit of wheat. It is evident by inspection, that this is not determined by the cold of winter; for spring wheat would not be affected by it; and even if sown in autumn, in these far northern regions, the seeds would be effectually preserved from the rigors of winter, by that thick mantle of snow, which becomes thicker and more lasting towards the north. The temperature of the air exerts no influence on seeds of plants buried under snow. Nor does the mean temperature of the year exert any effect; it is seen ranging 9 degrees, while the summer temperature varies only 3 1-2 degrees. The summer temperature alone defines the limit of northern wheat cultivation, and this is an isotheral line of 57·4 degrees. Yet it is found, that there are places, where, as in Russia, the means of spring

and autumn, both depending on that of winter in part, are too low to allow wheat to be raised under this line of 57·4 degrees. In truth, the relation of climate to cultivation cannot be accurately determined without observations on the mean temperature of the days which elapse between sowing and harvest, and to this point the philosophic farmer should direct his attention. In our country, the isotheral line of 57·4 degrees, starting from Labradore, 51 degrees, and passing between Hudson's Bay and Lakes Superior and Huron, 50 degrees, then turning north it approaches 58 degrees. At Cumberland House, 54 degrees north, Capt. Franklin found fields of barley, wheat, Indian corn. The line approaching the Pacific ocean turns more southerly to compensate the increasing humidity. As the limits of barley mark the boundary between the races of shepherds, and hunters and fishers, and thus presents itself in a moral view, so the limit of wheat becomes interesting from coinciding in some parts with that of fruit trees, as apples and pears, and also with that of the oak. The whole aspect not only of agriculture, but also of the orchard and forest changes at once on approaching the isotheral line of 57·4 degrees, the northern limit of wheat. It would be easy to extend these remarks to rye, still the staple food of a large part of the population of Europe, and to oats, little used for food for man out of the "land o' cakes," yet growing in Norway, as high as latitude 65 degrees. Each of these grains has a distinct isotheral line parallel to that of wheat and barley. Indian corn and the potato have each its isotheral line. Turning to the equatorial limits of the grains it will be found, that extreme heat arrests their cultivation. Observations in these regions, and experiments peformed by pro-

found vegetable physiologists, confirm this statement. They have proved that the seeds of the food-bearing plants, even after germination has began, can support greater degrees of drought and heat, than ever occur in the hottest climates. The grains all germinate in a soil of a temperature from 104 to 105 degrees, and require at least from 116 to 120 degrees to arrest this process. Barley ceases to germinate at the lowest temperature. After barley, follows wheat, then rye. Indian corn endures the highest heat, viz: 120 degrees, before its germination is arrested. The grains flourish under a mean annual temperature of from 77 to 80 1-2 degrees. Defining their equatorial limits, they are bounded not by lines of equal summer, but equal winter temperature; the reverse of their polar limits. Hence, climate, always determines the sowing season. In Bengal, wheat, barley, oats, are sown in October and harvested in March and April, while rice and maize are sown in May, to be harvested as with us in October. It is this line of equal winter temperature, or rather that of the coolest months, which allows the grains to be cultivated in many places within the torrid zone, and the line of 68 to 70 degrees, which constitutes the tropical limits of wheat culture, varies between 20 and 23 degrees latitude. The other grains enduring from 5 to 7 degrees lower temperature, are found in higher latitudes.

27. The wide belt of our globe, comprised within these limits, extending from 20 to 70 degrees north latitude, presents every variety of geological structure; yet, nowhere, in all this space is the quantity or quality of crops affected, by the chemical nature of the underlaying rocks.

28. A similar principle governs the growth and cultivation of the grain-bearing plants on mountains. Their limits are found at heights, which correspond to the latitude, which marks the isotheral line. In the Swiss Alps, the grains cease growing at the following heights.

Wheat	at	3400 ft.	corresponding	to lat.	64	deg.
Oats	"	3500 "	"	"	65	"
Rye	"	4600 "	"	"	67	"
Barley	"	4800 "	"	"	70	"

This shows a beautiful correspondence between latitude and altitude, and leads a step farther in the proof of this principle, that rocks do not affect the vegetation which covers them.

29. The space which has thus been surveyed, presents amid great diversity of rocks, a singular identity in chemical composition of the soil. These facts lead to the third principle of agricultural chemistry, ROCKS HAVE NOT FORMED THE SOIL WHICH COVERS THEM.

30. Everywhere, with the exception of the tops of some mountains, the rocks of the globe are covered, from a few inches, to some hundred feet in depth, with gravel, sand, clay, rolled stones, sometimes alternately with each other, sometimes in confused heaps. The best attested, and most universally admitted fact of geology, is, that the loose materials of our globe have been transported, from a few, to many hundred miles from their original situation. With a few exceptions, the soil which now covers rocks, has been derived from places distant, and from rocks distinct, from those on which it now reposes. This is peculiarly true of soil on limestone districts, which does not contain more lime than the soil reposing on granite.

31. Transportation of soil, is a fact so well estab-

lished, that it needs only to be mentioned. There has been a universal mingling of the loose material, soil, derived from worn down and mingled rocks.

32. The same uniformity of chemical composition characterizes soil, which characterized rocks; that is, great similarity, but not identity, and it is on limited patches only, that soil partakes decidedly of the character of the underlaying rocks.

33. The extensive analyses of soil, executed by the geological surveyor of Massachusetts, taken from every variety of rock formation, present a remarkable uniformity, both of chemical constitution, and mineralogical composition of the earthy ingredients. The same truth is presented by the analysis of soil from various parts of the globe. It is a conclusion, warranted by the widest examination, that the mineral constituent of 100 parts of the soil of our globe, is composed of sand or silicates about 89·28; salts of lime, about 00·85.—The terms salts and silicates, will be explained in the next chapter.

CHAPTER II.

CHEMICAL CONSTITUTION OF ROCKS, AND SOIL.

34. The geologist, the mineralogist, the chemist, each views rocks with a different eye. The geologist regards the rocky mass; the mineralogist, the simple minerals composing the rock; the chemist, the simple elements which compose the minerals.

35. Elements are substances which have not as yet been proved to be compound, as oxygen and hydrogen among the gases, or iron and lead among metals. Minerals are called simple which have certain definite, external, physical characters, though they may be composed of several elements. Rocks are called compound, which consist of several simple minerals, as granite which consists of quartz, felspar, and mica.

36. The only point of view which the farmer takes, is that of the chemist; his pole-star is "fruit and progress;" and his philosophy, guided by this, teaches the nature and mode of action of the several elements of minerals. Without a knowledge of the chemical constitution of minerals, the science which classifies and labels these is useless. The mineralogist merely names his mineral, labels it, and places it in his cabinet; yet a farmer must know a few of these names, and talk to the mineralogist in terms which he can understand. He

must give to the assemblage of elements which composes a mineral, that name which the mineralogist bestows on the assemblage of external characters, which determines the species.

37. The mineralogy of agriculture is no more than this, that the farmer be able, ever to connect with a certain name, a certain chemical composition. Hearing mica (which is isinglass,) named, he immediately connects with that, the chemical properties which belong to the species, as he would connect with the term isinglass, the physical properties of that substance; such as transparency, divisibility into thin plates, which are flexible and elastic.

38. The amount of this mineralogical knowledge is very limited. Seven simple minerals compose all rocks, viz: quartz, mica, felspar, hornblende, talc, serpentine, carbonate of lime. Other minerals are found in, but these seven compose all rocks termed geological formations, and which form the crust of the globe.

39. The chemical constitution of rocks, the nature, properties and relations of their elements, prove to be of the highest value, when it is known, that the elements of these seven minerals are also the earthy parts of all plants. The farmer should therefore be so far a chemist, as to understand the results to which the analysis of minerals conducts.

40. The number of elements which chemistry has detected, is fifty-five. Of these, some are metallic, others are earthy, others inflammable, or volatile. Of the fifty-five elements, thirteen chiefly compose all rocks. This includes the elements of water, or oxygen and hydrogen. Excluding the last, and retaining oxygen in its various compounds, there remain twelve substances only in rocks. Of

the earthy and metallic, eight; and of the volatile and combustible, four only are found in soil. These all are called by names so familiar, that their enumeration conveys at once an idea of their distinguishing properties. These twelve substances are divided, for the convenience of the farmer, into three classes. First, silicates—second, urets—third, salts. The term urets, is here only used provisionally, and it is by no means intended to burthen science with a new name, an act to be deprecated, where an old one will as well answer. But there is no old term, which includes the substances, to which, in the present subject, reference must be frequently made. It is more convenient to use a new term defined, than to enumerate by name, several substances, whose action in agriculture has a common character, whenever this action is mentioned. The word inflammable, or acidifiable combustible, the usual chemical designation might be used. But the farmer wants some more expressive term, which, while it conveys all that is intended by the common word, shall also remind him of the peculiar character of those compounds with metals, and with each other, which by common consent, end in "uret." This word, from the Latin, "*uror*," to be burned, seems well adapted to express the character of inflammability, while, by its addition to carbon, &c., it forms the common chemical designation of the class when combined with metals.

41. The substances which make up all rocks, may be conveniently divided into four pairs, which are, the alkalies, potash, soda; the alkaline earths, lime, and magnesia; the earths, silex, and alumina; and the metals, iron, and manganese. These form the first class, or silicates.

42. The silicates are formed into two divisions; first, that with acid, and second, those with alkaline properties; potash, soda, lime, magnesia, iron and manganese, have alkaline properties; silex, acid properties. Silex is commonly considered an earth, but truly it is not; and alumina, though generally acting as an alkali, sometimes acts as acid, as does silex or silica.

43. The inflammables, sulphur, phosphorus, carbon, and silicon, united with the bases of the alkaline division of the silicates, form the second class, or urets.

44. The four elements (43) united to oxygen, form acids. These acids, united to the alkaline division of silicates, form the third class, or salts.

45. The principles (41, 42, 43, 44) may be conveniently tabulated.

Twelve substances form all rocks, and they are divided into three classes—silicates, urets, salts.

FIRST DIVISION.

1st.—Silicates. Acid, Silex.

SECOND DIVISION.

Alkaline—Potash.
Soda.
Lime.
Magnesia.
Alumina.
Iron.
Manganese.

2d.—Urets. Carbon, Sulphur, Phosphorus, Silicon, } United with the bases of division 2d, class 1st.

3d.—Salts. Urets, with oxygen form acids, and these, with division 2d, class 1st, form salts. The

silicates are truly salts, but are distinguished not only by their stony, earthy appearance, but by their great insolubility in water.

Çarbonate of lime is a salt, with the insolubility, and earthy character of the silicates, but in agriculture it acts only as a salt, and will be treated of as such, and not as a rock formation. (14.)

46. The terms, salts, urets, silicates, may need a further explanation. Pearlashes and vinegar are well known substances. One is an alkali, the other an acid. Pearlash, has the alkaline properties of a bitter, burning taste, the power of changing vegetable blues to green, and pinks to blues. Vinegar has the acid property of sour taste, of causing a hissing or effervescence, when poured on pearlash. This action ceasing, there are neither acid taste nor alkaline properties. The characters of the vinegar and pearlash have disappeared. These substances have united, they have formed a new substance called a salt. Their properties are neutralized, and lost in the salt. This is no longer either pearlash or vinegar.

47. The fact to be observed in the action (46) is, that an acid and alkali mutually neutralize each other. The vinegar is said, in this case, in common language, to "kill" the pearlash. So soda, potash, lime, magnesia, iron, and manganese would all be killed or neutralized by vinegar; they would all be dissolved by it, and lose their distinguishing charaeters. In either case, a neutral salt would be formed. Such a class of salts, is termed acetates, being formed of alkalies, alkaline earths, or metallic oxides united with acetic acid.

48. Silex or silica, or the earth of flints as it has been called, is in its pure state a perfectly white, insipid, tasteless powder. In various combinations

of minerals, it unites with the alkaline class (42, 45,) forming neutral salts, termed silicates, from the silicic acid, for silica is an acid formed by the uret silicon with oxygen. Thus is formed, as in the case of vinegar, or acetic acid, (47) a large class in which are found silicates of soda, of potash, of lime, of magneisa, of alumina, of iron, and of manganese. This class forms the great bulk of all rocks and soil.

49. The seven substances last mentioned (48) are all metals united to oxygen. They are metallic oxides. If the oxygen is removed, and replaced by carbon, sulphur, phosphorus or silicon, combinations are formed, called sulphurets, carburets, phosphurets, siliciurets.

50. Urets are combinations of unmetallic combustibles, with metals in their pure, or unoxidated state.

51. Salts are combinations of unmetallic combustibles, with oxygen, and the metals in their rusted or oxidated state.

52. When the combustibles, carbon, &c., (43) are united with oxygen, they become acid; thus are formed carbonic, sulphuric, phosphoric acids. When these acids unite to the alkaline class, (42) salts are formed, called carbonates, sulphates, phosphates.

53. Hence, when a substance is named, for example, sulphate of lime, a definite idea of the nature of this is conveyed. It is, on the principles stated, at once known to be a salt, that is a sulphate, that is, sulphur and oxygen united to lime. So too phosphate of lime is seen to be a salt of lime.

54. If the thirteen elements, which enter into the composition of rocks, had each an equal tendency to unite with the other; or in other words, if

their affinities were mutual, then there would be as many different combinations as it would be possible to form with thirteen different substances. If these combined in all proportions, then the possible number of combinations, would be infinite.

55. This can never be. Affinity is not equally powerful. There is election or choice among the particles of inanimate matter. When the Creator impressed this property upon matter, He also limited its combinations. He assigned to each element power to combine with other elements, only in fixed, definite, invariable proportions. He gave to each its form, weight, and measure. And thus were limited, the number of combinations, and the proportions fixed, in which these combinations should ever, from the dawning, to the end of time, occur. The Genius of modern chemistry, has taught, that all bodies combine, only by infinitely small particles. Holding her balance over invisible elements, she has taught, that each can be weighed.

It is the relative, not the absolute weight, which chemistry determines. The mode may be thus illustrated: Take 9 lbs. of water, pass its steam over a known weight of pure iron turnings, heated red hot in an earthern tube. No steam escapes from the tube, only air which may be inflamed and burned. It is hydrogen gas, one of the constituents of water. That liquid has been decomposed. What has become of its oxygen? It has united with, and oxidated the iron. What proportion of the 9 lbs. of water did it form? 8-9ths. If the iron is weighed, it will be found heavier in proportion of 8 lbs. for every 9 lbs. of water evaporated. Whatever is the proportion of water used, 8-9ths are oxygen. Deducting from the 9 lbs. of water, 8 oxygen, the balance 1 is hydrogen. These are

respectively the weights of their combining proportions. Chemical theory supposes combination occurs, only by the ultimate, indivisible particles or atoms of matter. Hence, the combining number, is the relative weight of these atoms, referred to some one as unity. In these pages, hydrogen is considered as 1, or unity. As the atoms may be thus expressed by numbers, it is customary in referring to chemical compounds, to speak only of the number of atoms, in which each element enters into their composition. The modern system of chemical notation, substitutes for the name of the elements its first, or two first letters, and writes after it the number of atoms, existing in any compound, as the *powers* of roots, are expressed arithmetically by *exponents*. Where only single atoms combine, their exponents are omitted. Thus, H is hydrogen, O is oxygen; then water is H O, that is, one atom each of hydrogen and oxygen. C is carbon, O oxygen; then $C\ O^2$ is carbonic acid, that is, 1 carbon and 2 of oxygen. The combining number of carbon is 6, and of oxygen 8, then 1 carbon $=6$, and 2 oxygen $(8 \times 2)=16$. Then the atomic number of carbonic acid is 22, $(6+16=22.)$ One little conversant with chemistry is apt to confound the combining number with the number of atoms, especially when the first is called "atomic number." A distinction is to be here remembered, the atomic number is one thing, the number of atoms another. When it is said, that water is composed of 8 parts of oxygen to 1 part of hydrogen, by weight, an ultimate fact only is expressed. When it is said that water is composed of an atom of oxygen united to an atom of hydrogen, we express a theoretical opinion. The difficulty lies, in understanding how water can be both a combina-

tion of 1 to 1, and of 1 to 8; that 9 of water can yet be only composed of 1 to 1. This discrepancy vanishes, where the distinction is remembered, between the combining or atomic number, and the number of atoms. Water is an example, where single atoms are united. But cases continually occur where the combining number of one body unites to more than one combining proportion of another. In this case, as the atoms are indivisible, combination can occur only, by twice, thrice, &c., the quantity of that of the first compound; for instance, 1 carbon may be combined with 1 oxygen, forming oxide of carbon, or with 2 of oxygen, and form carbonic acid. There is, and can be no intermediate step. Having determined the combining atomic number of oxygen, that of all other bodies, may be found by determining how much of each is necessary exactly to unite with 8 of oxygen. For instance, the iron used in the experiment of decomposing water, increases in weight; if it is all equally oxidated, it is found to increase 8 lbs. for every 28 lbs. of iron used. If therefore, 28 lbs. of iron are used, and 9 lbs. of water, the iron may be wholly oxidated by the 8 lbs. of oxygen of the water. Deducting this from the total weight of the oxide of iron, 36 lbs. the balance is the combining or atomic weight of iron. The sum of $8+28=36$ is therefore the atomic weight of oxide of iron. The atomic weight of all compounds is the sum of the atomic weight of their constituents. The number of atoms in any compound, whose proportional constituents by weight are given, is found by dividing each by its respective atomic weight. For instance, the composition of carbonic acid above, gives in 22 parts, 6 of carbon, and 16 of oxygen. Each divided by its atomic weight, gives 1 carbon,

2 of oxygen, =22 of carbonic acid. So in a compound of several elements, having their proportions per cent. given; each divided by its atomic number, gives the relative proportion of the atoms. These reduced to simplest terms, and affixed to the letters or symbols of the elements, constitute what is called the chemical formula of this compound.

Three laws discovered by multiplied observation, confirmed by repeated experiments, govern all chemical science. These laws are:

1st. Bodies combine only in definite proportion.
2d. " " " multiple proportion.
3d. " " " equivalent proportion.

These are the laws of chemical combination. The atomic theory attempts to, and does account for them. Once admit the principle, that bodies combine only by indivisible atoms; these laws follow as consequences. If bodies only unite by atoms, atom to atom, their composition must be definite. If a body unites an atom to two or more of another, then as atoms are indivisible, the second or other added portion, must be a multiple of the first, by a whole number. When bodies unite in proportions which imply half atoms, it is because union has occurred between two atoms of one, and three atoms of another, as iron may unite with oxygen so as to be seemingly a compound of 1 iron to 1 1-2 oxygen. Truly this is a compound of 2 iron, to 3 oxygen. Again, if bodies unite only by atoms, the atom of one may be replaced by that of another; or, which is the same thing, the combining proportion of one may replace the combining proportion of another, for they are equivalent to each other. One body may be thus successively united to others, in doses which represent their atomic weights.

56. Calculating on this fixed principle, that the combining weight of any substance, is the quantity necessary to unite with 8 of oxygen, it is found, that the proportions in which the elements of silicates combine, are

8 oxygen,	8 silicon	=16 silica,
8	" 10 aluminum	=18 alumina,
8	" 20 calcium	=28 lime,
8	" 12 magnesium	=20 magnesia,
8	" 40 potassium	=48 potash,
8	" 24 sodium	=32 soda,
8	" 28 iron	=36 oxide of iron,
8	" 28 manganese	=36 oxide of manganese

When any of these oxidated substances unite to an acid, it is only in these proportions. The numbers are equivalents—that is, 48 of potash are equal in saturating power, to 32 of soda, or 28 of lime. All equivalents, entering into the composition of soil, contain the same quantity of oxygen. Hence, if from each of the above numbers in the third column, 8, the constant quantity, is deducted, the remainder represents the equivalent of the respective pure metals, which chemists represent by the termination in *um*, or *ium;* and hence are formed, potassium, sodium, &c.

57. The equivalent of sulphur is 16, adding 8 oxygen =24 parts, sulphuric acid is formed.

Of phosphorus is 12, adding 2 oxygen =16 parts, phosphoric acid is formed.

Hence, the equivalents of these acids are 40, 28, numbers produced, by adding the proportions of oxygen, to the respective bodies. These acids combine, in their above equivalent proportions, with the bases of silicates, forming neutral salts, or with two or more proportions of acid form super-salts, or

with a larger portion of base, form sub-salts, and thus form fixed and invariable compounds. Sulphate of lime, is therefore in proportion of 28 of lime, to 40 of acid. Carbonate of lime, 28 to 22. Phosphate of lime, 28 to 28, or neutral phosphate, or with a larger proportion of lime, the phosphate of lime of bones, or bone earth, so called; and the equivalent of each of these salts, is the number produced, by adding that of the lime, to that of the acid.

58. If sulphur, phosphorus, carbon, silicon, are added to the metallic base of silicates, (45) the combination is a uret—the combination can take place only in the equivalent proportions. It is thus evident, that soil, consisting of silicates, urets, and salts, is a fixed, unvarying, chemical combination of these substances, though in proportions, somewhat varied by local causes, yet presenting, in the mass, a great identity of composition. When the subject of the composition of the vegetable portion of soil, is discussed, the value of a slight knowledge of chemical notation, and of combining proportions will be manifest. It is not to be neglected, however unconnected it may seem with practical farming. The doctrine of chemical equivalents is important to the farmer, even if he pursues it no farther than to understand and remember the combining proportions of a few substances, known to him only by name; such are the common acids, oil of vitriol, aquafortis, spirits of salt, or sulphuric, nitric, and muriatic acids; the usual alkalies, ammonia, potash, soda, lime; acids and bases, which combine only in their equivalents. It is sometimes remarked, in agricultural experiments, with different salts, that equal quantities, if correct comparative trials are to be made, should be used. The doctrine of equiv-

alents, teaches not an equal, but an equivalent portion—that is, 28 of lime are equal to 48 of pure potash. It may assist the memory here, and furnish a good "rule of thumb," to recollect, that the three alkalies, ammonia, soda, potash, are to each other, as 17 : 32 : 48, or as 1 : 2 : 3, nearly. When the subject of manures is considered, the doctrine of equivalents will be found important, in determining their relative value. Though the numbers here used, are those of some chemists of high authority, they are not all universally admitted. They have the convenience of being small whole numbers. They are readily retained in the memory, and simplify the subject, by freeing the calculation from multiplication and division of equivalent numbers. They are easily apprehended, and for all practical agricultural purposes, correct.

59. Viewed in this light, rocks are masses of silicates. The simple minerals composing rocks are truly only silicates in fixed proportions. The simple minerals are quartz, felspar, mica, hornblende, talc, serpentine. Their composition is presented in the following

TABLE OF CONSTITUTION OF SIMPLE MINERALS.

	Silex.	*Alumina.*	*Lime.*	*Potash, or Soda.*	*Magnesia.*	*Oxides of Iron and Manganese*
Felspar	66·75	17·50	1·25	12·00	....	·75
Mica, grey	50·82	21·33	....	9·86	....	9·08
" brown	40·06	22·40	....	4·50	....	1·79
Hornblende,—including trap rocks	45·69	12·18	13·83	....	18·79	7·32
Talc	58·2	....	....	water	33·2	4·6
Serpentine	43·07	0·25	0·50	12·75	40·37	1·11

In each, the silex acts as an acid. This is not only the most constant, but the most abundant ingredient of rocks. Next is alumina. The average quantity of these elements in the most important rocks, is silica 62·79, alumina 25·15 per cent.

60. In each simple mineral, the alkaline bases (45) being combined with silica, a compound, or silicate is formed. In this case, the few simple minerals forming rocks, may be arranged in three classes, and it will be perceived, that notwithstanding their great variety of external appearance, their ultimate chemical composition resolves itself into classes of double, or simple silicates, in which silicate of alumina is united with potash, or lime, or with magnesia, forming thus, three classes only of simple minerals which compose rocks and soil.

1st. Silicate of alumina and potash forms felspar and mica.

2d. Silicates of alumina and lime with magnesia form hornblende.

3d. Silicate of magnesia forms serpentine and talc; and silica almost pure, is quartz.

61. The iron and manganese in the table, (59) are regarded as accidental mixtures of silicates of these metals. Silicate of soda is often present in place of potash, and this constitutes an extensive variety of the felspar family.

It will be observed, by the chemical reader, that truly eleven elements, excluding those of water, are found in soil. The division into twelve substances, including oxygen, is more consonant with popular ideas, and is adopted; though by this mode, silicon occupies a double position.

CHAPTER III.

PROPERTIES, AND CHEMICAL ACTION OF THE ELEMENTS OF SOIL.

62. THE bases of the silicates, have common properties, which are:

1st. Alkaline. Whatever may be our idea of the effect of an alkali, as exhibited by potash or soda, the same in kind, but in degree less, is exhibited by lime, magnesia, and alumina. Placing potash as the type of alkaline power, the same power, in a decreasing order is found in lime, magnesia, and alumina.

2d. They are, most of them, soluble in water. Potash stands here also first, and the solubility decreases in lime, magnesia, and totally disappears in alumina. This may have some connection with the fact, that widely diffused as it is in all soil, it is very seldom found in plants in large quantity.

3d. They exhibit great affinity for carbonic acid. The order of affinity is potash, soda, lime, magnesia; alumina, if it possesses it at all, exhibits it only feebly. The alkalies form soluble, and the alkaline earths, and alumina insoluble compounds with carbonic acid.

4th. They have all great affinity for water, combining with it, and forming what are called hydrates. Potash parts not with this chemically com-

bined water, by any heat which has been produced; lime and magnesia give up their water readily, at a red heat: alumina requires for this purpose, a full white heat. This is the only case, where alumina stands next to potash.

5th. They are all fusible, in the order of potash, lime, magnesia, alumina.

6th. They have already been described as definite combinations of metals, and oxygen (56). The same law governs their combinations with water. Such compounds are termed hydrates, from "*udor*," water. Water is a compound of eight parts of oxygen, and one part of hydrogen, forming one part of water, whose equivalent is 9. Taking the number representing the base, (56) or rather the basic oxide, the equivalents of the hydrates are obtained by adding to each, 1 part =9 of water, Thus—

Potash,	48	united with	9	water,	forms	57	caustic	potash.
Soda,	32	"	9	"	"	41	"	soda.
Lime,	28	"	9	"	"	37	"	slacked lime
Magnesia,	20	"	9	"	"	29	"	magnesia.

63. The same law pervades all these various combinations. There are strong resemblances in the alkaline family, which show their relation, yet each is marked with its individual peculiarities. Alumina stands alone, and seems a natural link connecting the silicates with the urets.

64. The gradual passage of the characters of the metallic elements of the silicates, into the unmetallic of the urets is observed. The first, show alkaline powers by combining with oxygen. Exhibited in the highest degree by potash, and lowest in alumina, which shows both alkaline and acid properties. By the last, it is allied to urets, silicon, sulphur, phosphorus, carbon. The three last are so well known, that they need only to be mentioned.

65. The characters of the class urets, are as follows:

1st. They all combine with the pure metallic base of the alkaline division of silicates, (46) and form siliciurets, phosphurets, carburets, sulphurets. Thus are formed carburet of iron, or plumbago, sulphuret of iron, or iron pyrites, sulphuret of potassium, or liver of sulphur.

2d. The urets chemically combine with each other. Thus are formed sulphuret of carbon, and sulphuret of silicon.

3d. The urets all form acids, by combining with oxygen. Thus are formed sulphuric, carbonic, phosphoric, silicic acids. (53.)

66. While the metals, combine with oxygen only in one proportion, to form alkalies, producing it always, for each, of one uniform strength, the urets combine with different proportions, and form acids of different strength. The rule followed in naming the acids, is, first, that each is called after the substance forming it, the uret having *ous* added to it to designate the weaker, and *ic*, to designate the stronger acid; thus,

Sulphur 16+2 oxygen =16 is sulphurous acid.
" 16+3 " 24 is sulphuric acid.

So are formed phosphorous and phosphoric acids. Silicon forms but one acid, the silicic. It is the only member of the class urets, which requires a detailed notice of its properties.

67. Silicon, the base of the earth usually called silex or silica, forms, next to oxygen, the largest part of all rocks and soil. It has been already noticed, (64) how the earthy character, gradually increased from potash to alumina; and how this last, connected itself with the urets, and in the first member of this series, the earthy character appears

fully developed. It is the earth of flints, it is pure rock crystal, it is common quartz, agate, and calcedony, and cornelian. All these are silicon, acidified by oxygen, hence called silicic acid. It is this which forms with potash, the hard coat of the polishing rush; the outer covering of the stalks of grasses. Wheat, rye, oats, barley, owe their support to this covering of silica. It cases the bamboo, and rattan with an armor of flint, from which may be struck sparks. Entering into the composition of all soil, and hard and unyielding as it appears, forming not only the solid rock, but the delicate flower, which that supports; forming combinations with the metals of soil whose gradual decomposition is the birth of fertility, silicon demands a detail of its properties, commensurate with the high functions it performs.

68. Silicon, in the purest state, yet obtained, is a dull, brown powder, soiling the fingers. It dissolves in fluoric acid, and in caustic potash. Heated in air or oxygen gas, it burns vividly, and is partly converted into silica. Heated in a closed crucible, it shrinks very much, but does not vaporize. Heat has altered all its properties. It has become a deep chocolate color. It sinks in oil of vitriol, one of the heaviest of fluids; it will dissolve in no acid, except a mixture of nitric and fluoric; caustic alkali has no action on it, nor will it burn, in the intensest flame of air or oxygen gas. No other simple substance is so changed by heat. The only substance exhibiting analogous properties, is the uret, carbon.

Silicon burns in vapor of sulphur, and forms sulphuret of silicon. This easily dissolves in water, sulphuretted hydrogen escapes, and silica remains

in solution. These are facts of the highest importance in agriculture.

69. Whether heated or not, silicon is oxidated when heated with dry potash, and converted into silicic acid. In its pure state, this is a rough, gritty, tasteless powder. When heated, it runs like red-hot ashes, and the lightest puff blows it away. It is not melted in the strongest heat of a wind furnace. Silicic acid exists in two states, soluble, or insoluble in water. It is perfectly insoluble, after having been heated red-hot. Sulphuret of silicon, as has been noticed (68) dissolves in water, and gives silica, in solution. If this is evaporated, a jelly-like, sizy mass is obtained, which may be again dissolved in water. Acid, added to the solution, when evaporating, renders silica insoluble. Alkalies, boiled with insoluble silica, render it soluble, no change occurring in the alkali. These singular changes, are due probably, to a new arrangement of the particles of silica, produced by that power called *catalysis*, or the action of presence, that is by the presence of a third body, taking no part itself, in the action, but simply influencing the changes which occur.

70. Soluble silica exists in some minerals, and is produced, when a silicate is melted with an alkali, and dissolved in dilute acid. It is in consequence of this ready solubility of silica, that a small quantity is contained in all natural waters; associated with alkaline carbonates in mineral springs, it is often an abundant product.

71. The general properties, which silicic acid exhibits in its combinations, are these:

1st. All its compounds, with excess of alkali, are caustic, and soluble in water. Those with an excess of silica are mild, and insoluble. Glass is an

example of the last, and so are the rocks. Green bottle glass, is but a fused rock, a mixture of silicates of potash, soda, alumina, lime, magnesia, and iron. These are the silicates which have been already enumerated, (60) as composing rocks; and the amount, and origin of these several elements of soil, can now be conveniently understood. This is practical ground, and shows the value of chemical analysis of rocks. Whatever opinion respecting their origin, is adopted, and whether or not, granite is supposed to have produced the soil above it, or that it is only overlaid by granite drift, it is evident, from the table (59) that all granite rocks contain lime and alkali. These will be in proportion to the mica and felspar, for granite (35) is composed of these and quartz.

72. The composition of granite, composed of two-fifths quartz, two-fifths felspar, and one-fifth mica, is, in every 100 parts.

Silex,	74·84.
Alumina,	12·80.
Potash,	7·48.
Magnesia,	·99.
Lime,	·37.
Oxide of Iron,	1·93.
Oxide of Manganese,	·12.

In every 100 lbs. of granite, 7 1-2 lbs. of potash, and 3-8 lb. of lime. Differ, as opinions may, about the how, and the why, of the operation of lime, and alkali, it is evident, that unexhausted and exhaustless stores of these substances are already in barren pine plains.

73. Let it be supposed, that these are formed of the drift of granite, composed as stated, (72) and the amount per acre of lime and alkali, taking the soil only six inches deep, would be as follows. The

cubic foot of such soil weighs about 90 lbs. or at six inches deep, 45 lbs. The acre at this depth, contains 21780 cubic feet, which will afford 3626 lbs. of lime, and 73311 lbs. of potash, or nearly a ton and a half of lime, and thirty-six tons of potash.

74. The lime in such a soil, would be enough to supply that contained in a crop of rye, at 20 bushels per acre, for 7400 years; for at twenty bushels per acre, and at 50 pounds per bushel, each acre would afford 1000 pounds of grain, which contain nearly 1-2 lb. of lime, or ·049, (*Schræder*,) dividing 3626 by this, the quotient 7400 is the number of years the lime would supply the grain. Wheat will not differ much from rye, and if the time is diminished, by the amount of lime contained in the straw, it will be seen, that the actual amount of lime and potash, in what is called poor soil, will hardly begin to diminish at the end of a long lease, cropping every year, 30 bushels of wheat. Allowing thus, for example, the proportion of straw which such a crop would afford, to be about 5000 pounds, and this is not far from the truth; the straw gives 0·044 of its weight of ashes, or 220 lbs. of which, one-fifth is soluble in water, and consists of one-half of that dissolved, of potash. The spent ashes, or that part not soluble in water, contains 5·80 per cent. of lime. On these data, an acre of wheat straw, or 2 1-2 tons will give 220 lbs. of ashes, containing 22 lbs. of potash, and 10 lbs. of lime. The potash will last at this rate for the straw, three thousand years! It will be hereafter shown, that when the lime fails, the crop will not.

75. Were similar calculations extended to soil supposed to be formed of any other rock, the amount of lime and alkali, would still be seen to be almost inexhaustible. And whether rocks be sup-

posed or not, to form the soil over them, it may be established, as the fourth leading principle of agricultural chemistry, ALL SOIL CONTAINS ENOUGH OF LIME, ALKALI, AND OTHER INORGANIC ELEMENTS, FOR ANY CROP GROWN ON IT.

76. These elements do not exist in soil, free; they exist as silicates, urets, or salts, compounds regulated by the unbending laws of affinity, and fixed, as are the laws of gravitation. The decompounding of these combinations, or the gradual decay of rocks and soil, takes place also by similar laws. Gradually acted upon by the carbonic acid of the air, the agency of growing plants, the action of various salts, formed by urets, in atmospheric exposure, the silicates yield to new affinities. The alkalies, freed from the embrace of silica, dissolve, and are borne seaward, the silica itself is dissolved by the water used for drink; the insoluble alumina remains, forming the great mass of clays, or mixed with granitic sand, forms loam.

77. Felspar, mica, hornblende, are constantly acted upon by air and moisture. This action is chemical. It is twofold. 1st. The action of the carbonic acid of the air, or of carbonates, upon silicates. The potash, or alkaline part of the silicate is by this means separated. The mineral no longer held by the bond which had held its components, falls into dust. The silica, lime, alumina, magnesia, thus form the finer portions of soil. In obedience to a well established fact, in chemistry, the seemingly insoluble silica, and alumina, and magnesia, in the very moment of their disunion, are each soluble in water. They may then be taken up by plants, or dissolved by various acids, formed in the soil, form salts.

78. The second mode of action, of air and moisture, is upon the urets, upon the sulphurets, the phosphurets, and silicurets. The action of air upon all these is, to oxidate, both the metallic base, and the unmetallic element. In a word, the urets, by air and moisture, become salts; the unmetallic part, becoming acid, and the base an oxide, which combine.

79. The fact most important to the farmer, in these changes is, that the urets are continually, in all soil, becoming salts. Whenever iron pyrites, or sulphuret of iron is found, and it is very widely diffused, exposure to air and moisture, acidifies the sulphur, it forms oil of vitriol, or sulphuric acid. This immediately combines with iron, and forms copperas, or sulphate of iron, or with alumina, forming alum, or with lime, forming Plaster of Paris, or with magnesia, forming Epsom salts; all these are salts, and liable to be decomposed, by any free alkali, which may be produced, by the decomposition of silicates.

80. Among the most abundant salts in soil, arising from the actions (79) are those, which are very insoluble in water, and not liable, therefore to be drained off, when not required by plants. These are sulphate of lime, and phosphates of lime, and of alumina, and iron. The sulphate of lime is partially soluble, and hence, is found in all river and spring water; but phosphates are more insoluble, and are always found in soil.

81. That sulphate of lime might possibly exist in soil, has been admitted by all who understood the actions, (79) and adding to this the fact, of the gradual decomposition of the silicates, by carbonic acid, the function of sulphate of lime in soil, was easily admitted. The double silicates of lime and

potash, are universally diffused, and in the order of affinities, sulphates of alkalies, and of lime result.

82. It is not so easily understood, how phosphate of lime should exist in soil. The true source, both of sulphate, and phosphate of lime, and of the solubility of silica, is yet to be detected, by exact chemical analysis. It is to be looked for in the sulphurets and phosphurets of silicon, which probably exist in rocks. The action of sulphuret of iron, as explained, would demand its universal diffusion, to account for the presence of sulphate of lime. Sulphuret of iron, must either now exist, or have ages ago existed, as widely diffused as the silicates. But though common in rocks, its presence as a sulphuret, will not account for the quantity of sulphate of lime found in soil. Vast quantities of this salt are annually borne off in crops; while at the same time, a large portion of that hardest, and as is generally supposed, utterly insoluble earth, silex is withdrawn by every plant which grows. How is this rendered soluble?

83. This question may be answered, if it be admitted, that a large portion of the silica of rocks, exists as a sulphuret of silicon. The action of air, and moisture upon this, will be understood by refering to section 68, where it is stated, that sulphuret of silicon, is decomposed by water. The sulphur, in this case, is evolved as sulphuretted hydrogen gas, the silica deposited, and in this state, is abundantly soluble in water. The sulphuretted hydrogen, would act on the lime of the silicates, and gradually, sulphate of lime would be formed. Here is an abundant source, not only of the solubility of silica, a point always of difficult explanation, in vegetable physiology, but also of the production of sulphate of lime.

84. Similar remarks are applicable to the presence of the phosphates of lime, and iron, and alumina in soil. Phosphate of lime is not a very universal ingredient in rocks. In certain localities it is abundant, yet its occurrence is too rare to account for the vast amount of phosphate of lime in soil. The phosphorus possibly exists, in combination with silicon, as phosphuret of silicon. The effect of air and moisture on this, has already been explained, and accounts for the production of phosphates in soil. Similar remarks are applicable to the source of the chlorides or muriates; for instance, common salt in the potash of commerce. May not their source be in chloride of silicon? These are conjectures, but conjectures only because, refined as modern chemical analysis is, it may not be so delicate, as to detect the possible combinations, which nature presents in silicates. What is the source of that phosphoric odour, produced by the friction of fragments of pure quartz on each other? If not due wholly to electrical excitement, may it not arise from the presence of phosphoric elements? The elements are Protean, and assume new dresses, by the very processes adopted to unfold them. Whatever may be their origin, their constant presence leads to this fifth principle of Agricultural Chemistry, ALL SOIL CONTAINS SULPHATE AND PHOSPHATE OF LIME.

85. This principle is of the highest importance in agriculture. The author of these pages, stated the fact, to the Geological Surveyor of Massachusetts, in 1837, and it was published in his Report. Slowly admitted at first, the fact, that phosphates exist in all soil, has been established by the widest observations. Its proofs are both chemical and agricultural. The chemical proof is found in the extensive

analyses of soil, contained in the various Geological Reports, especially those of Massachusetts, published within a few years. The agricultural proof, may be stated in a few words.

86. First, the bones of all graminiverous animals, contain about half their weight of phosphate of lime. It can be derived only from their food, and that only from the soil. Hence, the soil contains phosphoric acids in some chemical combination. Secondly, the actual result of chemical analysis, confirms this statement. Beets, carrots, beans, peas, potatoes, asparagus, cabbage, afford phosphates of lime, magnesia, and potash, varying from 0·04 to 1 per cent. of the vegetable. Indian corn contains 1 1-2 per cent. of phosphate and sulphate of lime. Rice, wheat, barley, oats, all contain notable portions of sulphate and phosphate of lime, not only in the grain, but in the straw. Smut and ergot, show free phosphoric acid. Cotton gives 1 per cent. of ashes, of which 0·17 are phosphates of lime and magnesia. The cotton consumed weekly, in the Lowell Mills, is 400,000 lbs. containing 680 lbs. of phosphate of lime, and this would furnish the bone-earth, for the bones of 17 horses, allowing 90 lbs. to each skeleton, of which 40 lbs. would consist of phosphate of lime. That beautiful yellow powder, shed by pine forests, the pollen of its flowers, wafted about in clouds, and descending with the rain, covering the surface of water with its sulphur-like film, is composed of 6 per cent. of phosphates of lime and potash. The ashes of all wood, contain sulphate and phosphate of lime. Garget contains in its leaves beautiful crystals of phosphate of lime and ammonia, whilst the little delicate plants, growing almost beneath its shade, mouse-ear-everlasting, and early saxifrage, contain in their leaves carbonate of lime.

CHAPTER IV.

OF THE ORGANIC CONSTITUENTS OF SOIL.

87. The mineral elements of soil, become part of plants. Under the influence of the mysterious principle of life, they no longer obey the chemical laws, but are parts of a living structure. Life suspends all chemical laws. It organizes inorganic matter. To what laws obedient, to what purposes subservient, are the elements of soil during the brief moment, in which they are endowed with life, it is not intended to inquire. Plants by their living power, select from the fifty-five elementary substances, fifteen only; of these, three are gaseous, oxygen, hydrogen, nitrogen; one, chlorine, exists only as a component of a salt, as in common salt; seven belong to the class silicates, second division, and four to the class urets. (44.)

88. Every plant does not, nor does every part of the same plant contain the same elements; but every part of the same plant, at the same age, probably contains the same elements, united in definite proportions. Whenever plants die, their elements are again subject to the laws of affinity, and during the decay of vegetables, they return to the earth, not only those substances which the plants had taken from the soil, but also those which have been

elaborated by their living structure. The former are silicates and salts, or the inorganic elements; the latter, are the organic parts of soil.

In the first edition of this work, chlorine was not enumerated as an element of plants. Its presence in them was considered accidental, because its source was not detected in the rocks, from whose ruins, soil has been formed. Plants are good analysts, and may detect elements, where chemistry cannot; yet it is difficult to believe, that chloride can exist as abundantly in soil, originally, as their presence in plants indicates, and yet elude our processes. The possible existence of chloride of silicon has been noticed. If this is not the source of the chlorine of plants, it must be supposed to be evaporated as a chloride from the ocean, and consequently to exist in that state, dissolved in air. If derived from this salt in soil, then that is extraneous. Its origin was suggested to be oceanic. An examination of the rain-water, of each fall, since March last, has shown that this suggestion is correct. Probably muriates are universally contained in rain-water. As therefore, common salt, the chlorine, and soda of plants is derived by evaporation from sea-water, then as sulphate of lime has been detected in snow and hail, it becomes a question, whether other inorganic salts of plants, may not have a similar origin, and exist dissolved in air.

89. It is thus seen, that soil presents itself in a new view. Soil consists of two grand divisions of elements. Inorganic, and organic. The inorganic are wholly mineral, they are the products of the chemical action of the metallic, or unmetallic elements of rocks. They existed before plants or animals. Life has not called them into existence, nor

created them, out of simple elements. Organic elements are the product of substances once endowed with life. This power influences the elements, recombines them in forms, so essentially connected with life, that they are, with few exceptions, produced only by a living process. They are the products of living organs, hence termed, organic; and when formed, are subject to chemical laws. The number of elements in the inorganic parts of soil, is twelve. Oxygen, sulphur, phosphorus, carbon, silicon, and the metals, potassium, sodium, calcium, aluminium, magnesium, iron, and manganese. (56) The number of elements in organic parts of soil, does not exceed four, oxygen, hydrogen, carbon, and nitrogen.

90. The great difference between these two divisions, is this, that while the inorganic are simple combinations of two elementary substances, the organic, are combinations of three or four elements, but never less than three. These are variously combined. They have formed the great body of vegetable products; continually changing, the mere abstraction of a part of once of their elements forms a new product. The three elements, (89) exist generally in such proportion, that the oxygen and hydrogen would, by their union, produce water, without excess of either element, while the carbon would thus be liberated. It would be found free were it not also acted upon by air and moisture, and changed to carbonic acid. There is not oxygen enough in the organic part, to convert the carbon into carbonic acid, and the hydrogen into water. They are constantly changing, assuming new forms. This susceptibility of change, is the foundation of tillage.

91. The relation of agriculture, to silicates and salts, and to the composition of plants alluded to, (89) is of the highest interest. As silicates and salts compose all the earthy ingredients of soil, so are they equally constant in plants. The deduction to be drawn from this, is the sixth principle of agricultural chemistry, SOIL, CONSISTING CHIEFLY OF ONE SILICATE, OR SALT, IS ALWAYS BARREN.

92. It is not probable that soil, thus chemically constituted, exists. Admitting such to occur, even then, when dressed with the food of plants, it would not be fertile. The want of a mixture of earthy ingredients, which are as essential to the growth of plants, as are air and moisture, would effectually prevent the growth of crops. Only a portion of the elements, thus essential to plants, exists in them, in that state, in which they exist in soil. The silica, and potash, and lime, exist in plants as in soil, as silicate of potash, and sulphates and phosphates of lime and potash. When the ashes of plants are examined, we find carbonates of bases, which did not exist as such in the soil. A large portion of carbonates of lime and potash is found in ashes.

93. The origin of these, is to be sought in acids, which, by heat produce carbonic acid. This is the effect of heat upon all salts, formed of vegetable acids. Such are tartaric, malic, citric, oxalic, and acetic acids. The inorganic elements of plants, exist in combination chiefly with organic or vegetable acids. Each plant forms acids, in definite quantity, proportionate to the size, age, and part of the plants; the acid being constant, the bases to saturate them, will be equally constant.

94. A curious and beautiful chemical law governs this saturation, of the vegetable acids. It is the law of isomorphism, or the law of similar forms.

In minerals which are crystallized, it was formerly thought that similarity of external form, indicated identity of chemical composition. Later observation has established the fact, that minerals and salts exist, with perfect similarity of external form, yet of totally different chemical constitution. For example, the alumina in alum, may be replaced by oxide of iron. The form will not be changed; but all its chemical properties and relations are destroyed. This is called an isomorphous substitution, of one element for another, which produces a like form. The law of this substitution is, that the body, replacing another, must be, not an equal, but an equivalent proportion (56); that is, replaced by a proportion, containing the same quantity of oxygen.

95. The relation between agriculture and this law is so wisely and beneficially ordained, that it might well be called, a law of compensation, by the Natural Theologian. It is a well established fact, that plants, growing on soil, containing a due mixture of earthy ingredients, always select a due proportion of each, according to their functions; yet, if to such soil, an excess of either of the alkalies, or of the alkaline earths is given, an excess of potash, soda, lime, magnesia, may be taken up by the plants, to the exclusion of the usual proportion of another; hence, it may be established, as the seventh principle in Agricultural Chemistry, ONE BASE MAY BE SUBSTITUTED FOR ANOTHER, IN AN ISOMORPHOUS PROPORTION.

96. This is a very important law, in the agricultural relations of the inorganic parts of soil. Whatever may be the office, performed by these, in the living structure, none is of higher value than this, that they may be thus substituted, the one for the other. It is a fact, of the highest practical value. Its value

will be perceived, when it is considered, that if soil, containing originally all the elements, essential to a crop, becomes exhausted of one, yet another may be substituted, which combining with the organic acid of the plant, enables this to perform and perfect all its functions. If a crop fails, this is often charged upon the deficiency of lime in the soil. It has been already shown, that this is quite impossible, yet granting it true, so long as the law of isomorphism exists, so long may potash, soda, magnesia, that is, ashes, supply the place of lime.

97. Isomorphous substitutions in plants, relate only to the bases combined with the vegetable or organic acids. The mineral or inorganic acids, exist already saturated in the soil, as sulphates, phosphates, or muriates.

98. In consequence of the law of isomorphism, the oxygen in the bases of organic acid salts is a constant quantity, although ashes of the same plant may, by analysis, show a great diversity of composition; this can arise only from the fact, that the organic acids exist, probably in a definite proportion, in each family of plants. The acids are formed by the essential vital functions of the plant. To the perfection of this process, the silicates and salts of the soil, are not less necessary, than is life to the vegetable; but though one element may be substituted for another, yet no one element may supply the place of all others. This is a problem yet to be solved. Nor may any possible mixture of mere silicates and salts, give fertility to a barren soil. Fertility depends on the presence in soil, of matter, which has already formed a part of a living structure, or the organic elements of soil.

99. The inorganic are simple combinations; the organic simple in number, but wonderful complex

in their combinations. It is an established fact, that all complex compounds, are unstable. They are prone to form new combinations. The more complex, the easier decomposed is any compound. The more complex, the more liable to decomposition. Hence, the moment life departs, the plant or animal speedily undergoes new changes; its elements, which life had organized, obey now, not the law of life, but the laws of chemistry. The solids and fluids of a living body, when life ceases, escaping in part as air or gas, leave in a solid form, a substance, differing equally from any living organic product, and from inorganic elements. The product of the spontaneous decomposition of organic substances, still may exhibit the character which distinguishes this division, viz: complexity, great susceptibility and ease of decomposition.

100. Hence, in the products of the decomposition of organic bodies, a variety is formed, differing according to the circumstances, and the time, and progress of decay. However varied, there is one constant product of organic decomposition in soil, which is, ever the result of that process, in or upon the earth. This product is termed GEINE. *Ge* is the Greek for earth, and the suffix *ine*, is in conformity to chemical names, given to those vegetable or other organic products, whose independent existence has been determined; for example, quinine, morphine, &c.

101. While the great mass of organic matter of soil, is a well defined chemical compound, termed geine, consisting of carbon, hydrogen, and oxygen, there are traces of other general products of decay, which, in addition to the elements above, contain nitrogen. There is thus naturally pointed out, a division of the organic matter of soil, into two classes;

that which does not, and that which does, contain nitrogen.

102. The first class, or non-nitrogenous, comprises three substances, which have been termed, 1st, extract of soil, or of humus; 2d, geine, or humic acid; and 3d, carbonaceous soil, or humin. These are chemically the same, passing from one state to the other, without changing the relative proportions in which they were combined.

103. The second class, or nitrogenous, comprises two substances—crenic and apocrenic acids. These approach the three above named in their constitution, and by some authors, they are considered identical. The distinction of geine into nitrogenous, and non-nitrogenous, is founded in nature. These classes cannot mutually pass, the one to the other. The presence of nitrogen, in crenic and apocrenic acid, proves unanswerably, that the geine of chemists, cannot be composed of a mixture of these acids. They may not be made members of the class to which that element belongs, except by a change of chemical constitution. The question whether this ever occurs, though philosophically interesting, is of no practical consequence. Nor is it of practical utility to discuss the question, whether plants draw their carbon, hydrogen, oxygen, nitrogen, from the air, or from the soil. The nourishment drawn from air, depends on the great physical elements, air, temperature, moisture. Agriculture may not control these. It can palliate them, only by controlling that within its power, the state of the soil. With all above ground, the farmer has little concern. If plants are nourished, chiefly from the air, it is evident that the farmer, is concerned only to produce that state of the developement of the organs of plants, best adapted to the aspiration of

the aerial elements. This state is influenced chiefly by the soil. There is the farmer's true field of action.

104. Differ as opinions may, about its ultimate chemical constitution, and the mode of action of geine, whether by being taken up as a solution of geine, and of its compounds with the earths and metals, called geates, or only as a source of carbonic acid, the great practical lesson of all agricultural experience, teaches that geine is essential to the growth and perfection of seed; that without geine, crops are not raised. Geine is as essential to plants, as is food to animals. So far as nourishment is derived from the soil, geine is the food of plants. It may be laid down as the eighth principle of agricultural chemistry, GEINE, IN SOME FORM IS ESSENTIAL TO AGRICULTURE.

105. In all its forms, it is agriculturally one and the same thing. They are all included in the terms humus, or mould, or geine. Geine, in its agricultural sense, is a generic term. It includes all the decomposed organic matter of the soil. It concerns the farmer less to know the chemical constitution, than it does the practical, agricultural value of a class of compounds, termed geine. Restricting that term to the definite compound, which chemists call geine, an account of its relations, will convey a full idea of whatever other organic compounds are found in soil.

106. It has been stated already, that geine is the product of decomposition of bodies, once endowed with life. For the present purpose, it may be considered, as the result of vegetable decomposition.

107. Life, and the manner how plants grow, may not be understood. Growth is a living process.

Decay is a chemical process. Its laws are not only understood, but its products may be limited, controlled, hastened. Decay is fermentation, and this marked by its several stages, ends in putrefaction. Putrefaction is the silent and onward march of decay. Its goal is geine.

108. If dry vegetable matters are soaked in water, that is soon discolored, a product of decomposition is obtained; its peculiar character is, solubility in water. This solution, being exposed to air, soon becomes filled with little flocks, which gradually subside. This sediment is still a very little soluble in water, but so very sparingly, that it may be said to be insoluble. If the sediment is exposed a little time, to air, it regains the property of solubility in water, is easily dissolved in part, by potash ley, or any alkaline ley, whether caustic or mild.

109. The original brown solution may be considered as extract of mould. The sediment as geine and carbonaceous mould. These are either soluble or insoluble in water, or alkali; and hence, geine is divided into soluble and insoluble. The soluble is dissolved by water, by alcohol, by alkalies. The insoluble cannot be dissolved by any of these agents, nor by acids. The properties of geine, in water and alkali, or its behavior, as it is termed, is of the highest importance to the farmer, and are to be considered in detail.

110. The first and earliest product of decay, is that which is so easily soluble in water (108). If it could be at once seized upon, it would be, doubtless, a perfectly colorless solution, but it changes to a brownish color by exposure to air. This character is very common in solutions of organic matter. It is due in this case to the formation of the insoluble state.

111. If a little alum is dissolved in the watery solution of geine, and then a few drops of spirits of hartshorn, or sal volatile, or as it is termed by chemists, water of ammonia, are added, the earth alumina will be let loose from the alum, and it will immediately combine with, and precipitate the geine, that is, little flocks fall down gradually in the liquor. Hence, is derived an important character. Geine has a great affinity for alumina. If lime had been added to the solution of geine, the same effect would have followed. The same effect would be produced, by magnesia, by oxide of iron, and by manganese.

112. Alumina, lime, magnesia, oxides of iron, and manganese, will therefore in soil, immediately seize upon any soluble geine, and forming compounds with it, detain it there. The air and water will have now little action upon it.

113. But supposing that none of these elements (112) are present in soil, the fact stated (110) shows that all soluble geine, or solution of extract in water, soon passes to a mixture of soluble and insoluble, forming a dark brown powder. This is thus withdrawn, deep in the soil, from the immediate action of the air, and undergoes no further change. It may remain unchanged an indefinite time. If ploughed up, exposed any how to the action of air or moisture, it again becomes partly soluble in water, and exhibits its former characters, viz: great affinity for earths and metallic oxides. In this state it is VEGETABLE MOULD.

114. Vegetable mould then, is a mixture of the organic, and inorganic elements of soil. It is a compound of soluble geine, with earths and metals, mixed with soluble and insoluble geine. It is a chemical compound of organic with inorganic parts

of soil, mixed with a large portion of free organic matter.

115. The inorganic elements of mould are, 1st. Those which already had existed in plants, combined with vegetable acids. These last, by decomposition escape as carbonic acid, or in acid vapors and water, while the bases, or earths and oxides with which they were combined, remain, and are immediately seized upon by the forming geine; while the uncombined geine passes to the state of a brown coally powder.

116. The properties of this brown powder of mould, are, 1st. Partial solubility in water. Cold water dissolves only about one-twenty-five-hundredth part of its weight, hot water a little more. 2d. It is a perfectly neutral substance, exhibiting neither acid, nor alkaline properties, but all alkalies develope it in acid properties. In this state it is termed geic or humic acid. It is evident therefore, that geic or humic acid can never exist free in soil, so long as free bases are there present, as lime, alumina, iron, &c. It is produced by the action of alkaline bases, and immediately combines with them, forming salts, which are termed geates.

117. A third property of the brown powder of mould is, that after alkalies have acted on it, and developed acid properties, its solubility in water is considerably increased, while it continues in a moist state. If dried, in this acid state, it becomes almost insoluble in water.

118. The geates found in soil, have the following characters. 1st. All the alkaline geates are very soluble in water. The solution is of a brown color, according to its strength, from a light brown to a deep coffee color, almost black; acids precipitate this solution, and the geine falls in light brown

flocks, exceedingly bulky. This precipitate may be washed in water, rendered a little acid; but simple water, in consequence of the great solubility of geine, developed by its combination with alkali, will dissolve nearly all the precipitate.

2d. Lime water, added to a solution of an alkaline geate, forms a precipitate of geate of lime. It is to be observed, that a cautious and gradual addition of lime water forms a precipitate, which immediately re-dissolves. This is soluble geate of lime. It requires 2000 parts of water to dissolve it, being a very little more soluble than geine itself, and only half as soluble as lime alone. An excess of lime water precipitates all the geine as insoluble geate of lime. The properties of this insoluble geate of lime, are,

119. 1st. Almost perfect insolubility in water and alkalies.

2d. Decomposable by alkalies.

120. Geate of magnesia is easily soluble in water. It is the most soluble of all the earthy geates. It requires only 160 parts of water to dissolve one of geate of magnesia. It is decomposable by alkalies, and then both acid and base are dissolved. The geates of lime and magnesia when exposed to air, absorb carbonic acid; a salt is formed, containing an excess of geine, that is, the carbonic acid unites with a part of the lime. These super-geates, as they are termed, are always much more soluble, than the neutral geates.

121. Geate of alumina, is soluble in water, and in alkali, without decomposition. It requires 4200 parts of water to dissolve it, but is abundantly soluble in alkali.

122. Geate of iron requires 2300 parts of water to dissolve it. Like geate of alumina, it dissolves easily in alkaline carbonates.

123. Geate of manganese requires 1450 parts of water to dissolve it, and though soluble in ammonia, is insoluble in potash or soda.

124. The properties of the geates are of the highest practical importance. The three earths, lime, magnesia, and alumina, are universal constituents of soil, and the two first are constantly present in plants. In their relation to geine, these all combine with that, they all form soluble compounds, in the moist state, but after having been thoroughly dried, these geates are insoluble, even sun baking diminishes their solubility. In this dried state, they are earthy powders, and have long been mistaken for earthy portions of soil. The fact, that lime and magnesia form super-salts, (120) may help to explain why the free use of lime, may often require a long time to develope any beneficial effects. At first, its action renders the geine insoluble; and it is only when by exposure, the lime is changed in part to a carbonate, and thus rendered inert, that a super-geate of lime, which is very soluble, forms and begins to show its effects upon vegetation. The easy decomposition of geate of lime, by alkaline carbonates, teaches also, that if to geate of lime is added an alkaline carbonate, the geine may be dissoluble, and brought into use. It is probable, that when land has been overlimed, the evil can be corrected only, by the use of ashes. The carbonate of lime will act on the silicates, as will be hereafter shown.

125. The properties and relations of geine with water, are also of the highest agricultural value (116). The great insolubility shows at once how small must be the amount of this portion of soil, which can be ever removed by drainage or filtration, by flood, or rain, and that in the practice of

irrigation, very little effect can be due to the solvent power of water on geine. Its almost total insolubility, seems a wise provision, of a far-reaching Providence; that an element of soil, which has been and can be produced, by the decay of organic bodies only, and chiefly by plants on its surface, should not be borne away by the first falling shower.

126. Not less important to the farmer, are the relations of geine to alkalies, its solubility is wonderfully increased by their action; this is a most valuable, because available property; it allows the farmer to bring into use, by the application of alkalies, the geine, which, in its insoluble state is quite useless. This remarkable property, is not confined to that portion of geine, which it may be supposed, is chemically combined with alkali. Alkali, by the mere action of presence, by its catalytic action, which will be hereafter explained, renders an indefinite, but large quantity of geine soluble in water. This is a principle of high practical value, and were the results of the principles detailed in the foregoing pages, to terminate in this fact, that alone rightly pondered, would account for a vast number of facts, in vegetable physiology, and lead to new views in the pursuit of agriculture, not less important than practical.

127. Hitherto the action of geine on soil only, has been considered, and its chemical composition pointed out, sufficiently for all practical purposes. The chemical proportion of the elements of geine is unconnected with the practical question, how far it is essential to plants. The fact, that the most barren soil contains these elements in vast quantity, that exhausted land is nearly equally rich in these, as is the highly productive, has been overlooked. The amount of nitrogen in geine, even in

exhausted soil, is sufficient to supply that element, to several crops of grain. The amount of carbon, oxygen, hydrogen, and nitrogen, in a poor, sandy, barren soil, has been proved, by chemical analysis, to be not less than 34 tons per acre, taking the soil at only a foot in depth. If the light of modern chemistry, shall hereafter teach, that these are never taken from the geine of soil, it will teach also, what the true action of geine is. If no approach to the solution of this important question, has yet been made, still the absolute necessity of geine in soil, is admitted by all practical men. Some attempt to explain this fact, will be presented in the next chapter; and the following appendix may be omitted by those to whom practical results are of more value than speculations of philosophy. It is hoped, however, that the new and important analyses, contained in this appendix, will amply repay the labor of studying their results, now for the first time laid before the American farmer.

APPENDIX TO CHAPTER IV.

HISTORY OF GEINE.

Some account of the chemical history of a substance which has caused no little discussion in late agricultural reports, and publications, may not be here misplaced. It may tend to soften the doubts of those who are, and with reason, apt to mistrust the utility of a substance, upon whose chemical nature, there is such an apparent difference of opinion. If farmers are to wait till doctors agree, there will be no harvest. Happily this discussion is in no wise connected with the practical application of geine. It is a difference about names, not things. In 1797, Vauquelin, a distinguished French chemist, gave an account of a substance which had exuded from the bark of an elm tree. It was a shining, brittle, black substance, insoluble in alcohol, soluble in hot water, with a brown color, and contained potash.

In 1802, Klaproth, a Swedish analyst, received from Palermo, a specimen of this elm gum, and found it contained a portion of resinous matter, and confirmed Vauquelin's observations. In 1810, Berzelius, the most acute chemist of the age, in experimenting on the barks of various trees, noticed products similar to the elm gum, particularly in pine bark, Peruvian bark, and especially in the elm, whose properties will be presently mentioned; but

he not only gave these products no name, but pointed out marked differences between them. The substance found in pine, is allied to what is called pectic acid, that in Peruvian bark approaches starch, while that from the elm is only a variety of vegetable mucilage.

In 1812, James Smithson, an English chemist, gave to the Royal Society of London, an account of his experiments on elm gum, which he had received from the same place and person, who originally sent the article to Klaproth. Smithson thought the substance more allied to extractive matter, than to resin, and noticed that it contained 20 per cent. of potash. A similar substance obtained from the exudation of an English elm, contained a larger per centage of potash, but no trace of this new substance was detected in elm sap.

In 1813, Dr. Thomas Thomson, the Coryphæus of British chemists, experimented on this elm gum in its several varieties, and embracing the prevalent opinion of its distinct nature, not however, because prevalent, but from his own researches, erected it into a distinct vegetable principle under the name of ULMIN, from *ulmus*, the Latin for elm. He confounded under this name, the several products noticed by Berzelius, in bark; and hence, thinks there are several varieties of this substance, though Berzelius does not countenance this idea. Thomson was the first who ever procured ulmin pure, but this was not the elm mucilage, but the extractive matter, and he thus gave the name ulmin, to the apotheme of Berzelius.

Not long after this name had become the property of Chemists, Braconnot found, in experimenting on the action of alkali, on woody fibre, that a substance was produced analogous to elm gum and

the varieties of ulmin, and in 1830, Boullay noticed that ulmin had acid properties, and gave to it the name of ULMIC ACID.

The properties and relations of ulmin and of ulmic acid, now engaged the attention of many expert chemists. It was found to be the product of a great many vegetable decompositions by various agents, by alkali, by acids, earths, oxides, by fire, by water. All these hasten the process of decay. As a general law, it may be stated that all substances oxidating, and gently acting on organic matter, produce ulmin. Hence it was found in a vast variety of substances, and even cast-iron was found to contain about 2 per cent. of a compound, so analogous to ulmin, that it is so called. But above all, it was found to be the great product of spontaneous decay of plants, and hence existed abundantly in peat and soil. Sprengel, directing his attention particularly to its existence in soil, before that form of it was universally allowed to be identical with ulmin and ulmic acid, bestowed on it the name of *humic* acid, from the Latin, *humus*, or mould. Sprengel investigated minutely the various salts of this substance, and first endeavored to determine its chemical constituents.

Boullay soon followed in the same path of investigation, and with almost similar results. There were marked differences between all the forms, yet observed, that is, between elm gum of Palermo, the product of bark, the artificial ulmin of Braconnot, and that of soil. A multitude of different, but analogous substances were confounded under a common name, which began to be applied to the matter of all vegetables, which after having been treated with alcohol and water, yielded to alkali a solution, precipitable in brown flocks, by an acid. Under these

circumstances, Berzelius objected to the term altogether, and if there is a substance to which he would apply the name ulmin, it is to the mucilage of elm. As this has been the source of no small confusion, an account of it may be here introduced. Elm bark is treated with alcohol. The tincture is evaporated dry, and the extract treated with water, which dissolves a brown extractive matter, leaves an insoluble residue, which, being treated with ether, leaves a small quantity of a brownish matter, analogous to the extractive of chemists, or the brown apotheme of Berzelius. The sap of elm contains acetate and carbonate of potash. Here, then, are all the elements of elm gum, as examined by Vauquelin, Klaproth, Smithson, Thomson. Not only the elm, but other trees, under diseased action, exude these matters, and under the influence of air, and the potash, the diseased exudation from the elm bark, is changed to true ulmic acid, which unites with the potash, and both with the mucilage. The mucilage, may, by processes, not here necessary to be detailed, be procured pure, as a hard, opaque, colorless, insipid, and inodorous gum. It moistens easily, swells in water, becoming a semi-transparent mucilage. It is insoluble in alkali, affords no ammonia by dry distillation. Boiled with alkaline ley, it affords a clear mucilaginous liquor, which browns by being exposed to air. If this ley or solution is exactly neutralized by acetic acid, lime-water and salts of lime produce no precipitate in it, and it is only rendered slightly turbid by sulphuric, nitric and muriatic acids. It is not precipitated by acetate of lead, nor by sulphate of iron. With alcohol and sub-acetate of lead, it affords a mucilaginous precipitate. It is evident that it differs widely from artificial ulmin, and from ulmin of soil, and there-

fore, when Berzelius turned his attention to that, having advised the abandonment of the name ulmin, as inapplicable to any one substance, he bestowed on the ulmin of soil, the name of GEINE, from the Greek *ge*, earth. If a distinction is therefore to be maintained, it may be said, that ulmin is the product of life; geine, of decay.

The mass of matter called mould or humus, has many analogies with the artificial ulmin of authors; but taken as a whole, there are decided differences. These were noticed by Berzelius, and hence he divided, in an edition of his chemistry, (French translation of 1832,) the constituents of the organic part of mould or humus, into

1st. Extract of mould. 2d. Geine. 3d. Carbonaceous mould, or coal of humus, as it is often termed. He noticed that these mutually passed into each other. This shows a great similarity if not identity of chemical constituents. He did not pretend to determine that, but by his citing, in order to determine the elements of his No. 2, or geine, the analysis of Sprengel, of humic acid, and of that of ulmic acid by Boullay, it is evident that he considered his geine, identical with their humic and ulmic acids; but still he considered new researches to be necessary, to determine accurately the composition of either. Later experiments have not only confirmed the accuracy of Sprengel and Boullay, but the progress of discovery has proved the perfect identity of ulmin, humin, geine and of ulmic, humic, geic acid, and hence, Berzelius has withdrawn the name geine, and returned to that of humic acid, the usual term applied to the organic matter of soil. He could not, consistently, have gone back a step further, and substituted ulmin for geine, particularly

after he was violently attacked by Raspail, for abandoning that ancient, and much abused name.

The great distinction pointed out by Berzelius, in his three varieties of mould, was founded on their solubility or insolubility, by water and by alkalies. The author of these pages, while engaged in researches upon the action of mordants, and of cow-dung, in calico printing, began in 1833, before he had met with the work of Berzelius, had also noticed this marked distinction, and several other new and important facts relating to what he then called, from its analogies, ulmin. For all practical purposes, the distinction was enough. When a few years after, his attention was accidentally called to soil, the name of Berzelius, geine, was given by him to the whole organic matter of mould, or humus, and that matter was also, as a convenient practical division, separated into soluble and insoluble, including the various geic salts, which he detected in soil. In the edition of Berzelius, above cited, two other organic compounds are noticed, as being among the general products of putrefaction, traces of which Berzelius noticed in soil. These were called crenic and apocrenic acids, from "*krene*," Greek, for fountain, having been first detected in spring water. The French for spring, being "*source*," as if to make confusion worse confounded, the French translator of Mitscherlich, called these "sourcic and oxygenated sourcic acid."

The presence of nitrogen was detected by Berzelius, in crenic and apocrenic acid. This sufficiently distinguished them from geine, extract of, and carbonaceous mould. Though these acids were detected after the name of geine had been applied, yet the presence of nitrogen in these, would at once have led Berzelius to examine geine anew,

if he had any suspicion that it contained that element, or that he had mistaken the chemical nature of that substance. Unless we suppose, with Raspail, that nitrogen in these acids, exists, and acts only as he supposes it does in gluten, as an accident, or as an ammoniacal salt, it cannot be supposed that geine and these acids are identical, or can ever pass into each other. Nor has the progress of chemical discovery led to the abandonment of geine as a distinct principle. The existence of crenic and apocrenic acids, is not admitted, by some of the highest authorities of the day, the justly celebrated Liebig, and the no less expert and astute Graham, of the London University. Both admit, however, of ulmic acid and ulmin. Malaguti had procured, by boiling sugar with dilute acid, ulmic acid in distinct crystals. By long boiling in water, it is converted into ulmin, losing its solubility in alkali, without any change of composition.

The existence of these principles is recognized in the seventh edition of Turner's Chemistry, edited by Liebig and Gregory. The organic part, under the eye of Liebig, may be supposed to contain only well established chemical facts, and among these the results of Malaguti are given, under the names of sacchulmin and sacchulmic acid—the one is soluble, the other insoluble, in alkali; their constitution identical, and Boullay's analysis of ulmic acid is cited to establish their constitution. The whole doctrine of naming the elements of soil may be tabulated.

The Organic Elements of Mould, or Humus, by Berzelius's division.

1832.	1840.	
1. Extract of Mould,	1. Extract of Mould,	Vegetable extract of authors, apotheme of Berzelius.
2. Geine, ...	2. Humic acid, . . .	Ulmic of Boullay and others, sacchulmic of Liebig.
3. Carbon. mould, .	3. Humin, ...	Ulmin of authors, sacchulmin of Liebig.
4. Crenic acid, ...	4. Crenic acid, . .	Not admitted by Liebig and Graham; admitted by most others
5. Apocrenic, ...	5. Apocrenic acid	

It becomes, therefore, a question whether the term geine, is not the only proper term to be retained, applicable to the various forms found in soil; and its distinction into soluble and insoluble, well founded, for all practical purposes? This question may be answered by a reference to the analysis of geine. It includes not only that, so called in 1832, by Berzelius, the equivalent of which, by the table, is ulmic and humic acid, but also, all the three forms, except the nitrogenous. On this subject, during the imperfect state of organic analysis ten years ago, there may have been room for doubt; especially when the most consummate organic analyst of the age, Liebig, asserts that it is exceedingly difficult to estimate quantities, less than one half per cent. Even now, when the results of the most expert analysts, have thrown a shade of doubt over the determination of the true proportion of carbon, in carbonic acid, a proportion for so many years, considered one of the best established facts of chemistry,—it may be doubted whether later analyses of geine, approach nearer practical truth than those executed, almost in the infancy of the science. The constitution of geine as determined by Boullay

and Malaguti, admitted by all, to be worthy of confidence, is thus stated :—

	Carbon.	*Hydrogen.*	*Oxygen.*
P. Boullay, (Thomson)	56·7	4·8	38·50
" jr. (Lassaigne)	57·64	4·70	37·56
Malaguti, (Dumas)	57·48	4·76	37·06
Average,	57·30	4·75	37·70

But it may be said, that these refer only to the artificial productions. They may be quite other compounds, from that found in soil. Let us then place the analysis of geine of soil, as determined by Sprengel, side by side, with the average, above stated. This result of Sprengel, is given in Berzelius's "system" of 1832.

	Geine of Soil.	*Artificial Geine.*
Carbon,	58·	57·30
Hydrogen,	2·10	4·75
Oxygen,	39·9	37·70

The difference, it has been suggested, is owing "to the difficulty of procuring" geine, "pure, from soil." But the analyses of mould or geine, taken from decayed trees, show also, great differences. The process of decay, when air is freely admitted, combines a portion of the oxygen of air, with the hydrogen of the geine; the whole of the hydrogen is thus removed as water, while the oxygen of the geine, combining with the carbon, escapes as carbonic acid. There is not enough oxygen to convert all the carbon; hence, a portion remains. But if water, be present, during decay, and the air partially excluded, then, a portion of water yields oxygen to the carbon. In order to make correct comparative analyses, the substances should each have

proceeded to the same point of decay, and who may determine that? The geine of soil appears to have been favorably situated for the abstraction of its hydrogen, or in other words, it has formed water faster than carbonic acid. Still the proportions are so near those of the artificial, that it seems difficult to believe, that when these are so near alike, that their agricultural effects would not be identical.

While some deny the separate existence of crenic and apocrenic acids, and others assert, that they are identical with geine, they may be included in that; or excluding these, geine seems to be allowed on all sides, and under its several forms to be identically the same chemical substance, differing chiefly by its being soluble or insoluble, in alkali or water. The name and division adopted by the author, are not therefore inapplicable to the organic part of soil, whether the term geine be used generically or specifically, whether we "speak agriculturally or chemically." Still, the author is quite indifferent by what name the organic matter of soil is called, and perhaps he may be allowed to quote his remarks on this subject, as published in the third report on the agriculture of Massachusetts, by Mr. Colman, in 1838: "Whether we consider this as a simple substance or composed of several others called crenic, apocrenic, puteanic, ulmic acids, glairin, apotheme, extract, humus or mould, agriculture ever has and probably ever will, consider it one and the same thing, requiring always similar treatment to produce it; similar treatment to render it an effectual manure. It is the end of all compost heaps, to produce soluble geine, no matter how compound our chemistry may teach this substance to be."

Unless, therefore, better reasons for a change of

name are offered, than have yet appeared, the name geine will be retained.

During the last two or three years, Mulder, in whose analytical tact, all chemists place the utmost confidence, has examined the various forms of non-nitrogenous geine. He is now publishing the elaborate results of his long labor. The following sketch of these, which shed such a new light over this complicated subject, is chiefly drawn from Berzelius's Report for 1841, in which he speaks of them in high praise. While it will be seen that Mulder refers to the various forms of geine, under names used by Berzelius, he confirms the fact, that their great difference depends upon their being soluble or insoluble in alkalies, and has added a crowd of new facts, which connect all the forms in a beautiful and consistent manner. Stein had already, by repeating the experiments of Malaguti, arrived at products, whose analytical results, differed from Malaguti's. Mulder, repeating the process of boiling sugar with weak acid, and examining the product, has confirmed Stein's results, and also what has been advanced, that the forms of geine, thus produced, are, as Malaguti had observed identical in composition; and has shown, that the various forms, depend on the circumstances of the manipulation.

The catalytic action of weak acid, boiled upon sugar, produces first, ulmin, and ulmic acid. It is remarkable that these products are not formed in vacuo. This is due, not to the want of oxygen, but to the want of pressure. Boiled, under the pressure of hydrogen, or nitrogen gas, ulmin and its acid are produced. The products formed from sugar and weak acids, in a vacuum, are humin, and humic acid Ulmin, and ulmic acid are therefore the

primary products of this action in air or under pressure. If these are separated and again boiled with weak acid, in contact with air, they are changed into humin, and humic acid. These are therefore secondary products. Humin, and humic acid, are produced directly, by allowing a free, and abundant access of air. Ulmin, and ulmic acid, are then rapidly transformed to humin, and humic acid. Strong acid also hastens this transformation, but at the same time, changes humic acid to humin. Formic acid is always produced, and distils off during the process; and also two other new acids. The discoverer of one, was Peligot, in 1838, which Mulder now calls glucic acid, and he himself has added another, produced from this, which is called apoglucic acid. Passing over these, it is difficult to procure the other acids, and neutral bodies free from mixture. Whatever may be the quantity of sugar, or the circumstances of the manipulation, it is impossible to convert more than one-fifth of the sugar into ulmin, and ulmic, and humin, and humic acid. The other four-fifths are changed into formic, glucic, and apoglucic acids.

Having effected the change of one-fifth of the sugar, the ulmic and humic acids are separated from ulmin and humin, by potash. Ammonia cannot be used for this purpose. The reason will appear in the sequel. Having separated the several substances, their analysis presents the following results. The proportion, per cent., the author has deduced for the greater part, from Mulder's formulæ. What a chemical formula is, will be readily understood from (55). A formula is merely the true expression of an analysis, by the number of combining proportions. It presents to the eye at once, the constitution of any compound, and

affords a readier mode of comparing several bodies like-constituted, than does the proportion per 100 parts. That is added, for those, whose taste may have led them to omit the details. (55.)

But it may here be stated, that C stands for carbon, H hydrogen, O oxygen, Am. ammonia, a compound of 3 hydrogen, and 1 nitrogen; and Aq. stands for water (aqua), a compound of 1 of hydrogen, and 1 of oxygen; 2 aq. is 2 water.

Table of Composition of Ulmin, &c.

		Per 100 parts.		
	Formulæ.	*Carbon.*	*Hyd'gn.*	*Oxygen.*
Ulmin,	$C^{40}\ H^{16}\ O^{14}$	65·30	4·30	30·40
Ulmic acid,	$C^{40}\ H^{14}\ O^{12}$	68·95	4·23	26·82
Humin,	$C^{40}\ H^{15}\ O^{15}$	64·67	4·32	31·01
Humic acid,	$C^{40}\ H^{12}\ O^{12}$	69·25	3·42	27·33

It is thus seen, that ulmic and humic acid, differ from ulmin and humin, by containing the first 2, and the second, 3 atoms of the elements of water, more than the neutral bodies, from which they are formed. Ulmic and humic acids above, are supposed to be perfectly dry. Each may combine with a definite proportion of water, forming hydrated acids. In this case, they contain the same absolute and relative number of the same elements as do ulmin and humin. They are thus said to be isomeric with them. The composition of the hydrated acids is—

Ulmic, $C^{40}\ H^{14}\ O^{12}$ $+$ 2 aq. or 2 hydro. and 2 oxyg.
Humic, $C^{40}\ H^{12}\ O^{12}$ $+$ 3 aq. or 3 " 3 "

These acids combine with bases. If these acids are dissolved by ammonia, and precipitated by an acid, they fall combined with ammonia. Ulmate of ammonia, precipitated by metallic salts, forms double salts of ammonia and a metallic oxide. The composition of these salts of ammonia, is—

Ulmate of ammonia,	C^{40} H^{14} O^{12} + am. +2 aq.				
Humate "	C^{40} H^{12} O^{12} + am. +3 aq.				
Or per cent.	*Carb.*	*Hyd.*	*Oxy.*	*Nitrog.*	
Ulmate of ammonia,	64·75	5·06	26·92	3·97	
Humate "	64·58	4·22	27·46	3·74	

Mulder, having thus shown the composition of these artificial products, proceeds to trace similar natural products in peat, decayed wood, and soil. Here his labors have a direct bearing on agriculture. He points out their relation with those above, in so clear and masterly a manner, that it is impossible not to believe, that in agriculture, the artificial and natural products would produce like effects. In the natural formation of these substances, Mulder remarks generally, that during decay, without free access of air, ulmin and ulmic acid are formed, as in peat of a brown color, while, as in black peats with free access of air, humin and humic acids are produced from the primary products. This agrees with his experiments, in air and a vacuum. Peat of a brown color, having been treated with alcohol to remove all resinous matter, was then treated with carbonate of soda. All the soluble matter was thus extracted, that is, the ulmic acid. The insoluble geine, is ulmin. The soluble, precipitated, has all the characters of the ulmic acid of sugar. It differs only in this, it may not be heated above 140° Fahrenheit, without decomposition, and then produces formic acid, and water. Sugar-ulmic acid, undergoes this change at 195° F. Humic acid was prepared by a similar process, from black peat. It has all the external characters of sugar-humic acid. It differs by containing ammonia. Its soda solution, precipitated by muriatic acid, gave a precipitate containing one atom of humic acid, to one atom of ammonia. It loses no water at 140° F.

at about 180° it evolves ammonia; at 195° acetic acid. Humic acid was also prepared from the black mould of an old white willow, by a similar process as above. It suffers no change below 150° and at 163° it evolves water and acetic acid. Digested with caustic potash, it evolves ammonia. Continuing this digestion for twelve hours, and then precipitating the humic acid, it is found converted into ulmate of ammonia, with two portions of acid. It is a biulmate of ammonia, similar to that from peat. If digested with carbonate of soda, the product then is biulmate of ammonia, like that from sugar. Soil was treated by Mulder, first, with boiling alcohol, then with water, then with carbonate of soda, and the acids precipitated as usual, by muriatic acid. These precipitates were with difficulty obtained pure. They were repeatedly washed in cold water, dried, and again heated with alcohol, to remove every trace of crenic and apocrenic acid. This care of Mulder, to separate crenic and apocrenic acid from his geine, is new evidence that the last is not a compound of these acids. These being removed, the precipitates were again dried, as in fact, were all the products above described at 140° F. They were then analyzed. It is remarkable, that all these products are ammoniacal combinations. It is a combination, not as a salt, in which case, the geine of soil would be at once soluble in water, but a compound of humin and ulmin, or of their acids with ammonia, probably like the compounds of ammonia, with sulphates, and other salts. The whole may be best presented in a table, and that these natural, may be at once compared with the artificial products, these are also included.

TABLE OF THE COMPOSITION OF ARTIFICIAL AND NATURAL GEINE.

FORMULÆ.					PER CENT. Carbon.	Hydrog.	Oxygen.	Nitrog.
Ulmin,	C^{40}	H^{16}	O^{14}	. . . .	65·30	4·30	30·40	. . .
Ulmic acid,	C^{40}	H^{14}	O^{12}	(2 water less than ulmin.)	68·95	4·23	26·82	. . .
Humin,	C^{40}	H^{15}	O^{15}	. . . .	64·67	4·32	31·01	. . .
Humic acid,	C^{40}	H^{12}	O^{12}	(3 water less than humin.)	69·25	3·42	27·33	. . .
Hydrated ulmic acid,	C^{40}	H^{14}	O^{12}	+2 aq. . . .	65·30	4·30	30·40	. . .
Hydrated humic acid,	C^{40}	H^{12}	O^{12}	+3 aq. . . .	64·67	4·32	31·01	. . .
Peat ulmic acid,	C^{40}	H^{18}	O^{16}	(2 at aq. more than sugar acid.)	62·62	4·61	32·77	. . .
Peat humic acid,	C^{40}	H^{15}	O^{15}	(3 " ")	64·44	3·95	31·61	. . .
Willow mould humic acid,	C^{40}	H^{16}	O^{16}	(4 " ")	62·94	4·12	32·93	. . .
Fruit orchard soil,	C^{40}	H^{20}	O^{17}	+1 ammonia	58·49	5·60	32·52	3·37
Do. treated by am. and dried,	C^{40}	H^{12}	O^{14}	+2 "	56·24	5·98	31·27	6·51
Kitchen garden soil,	C^{40}	H^{15}	O^{15}	+1 "	61·65	4·54	30·24	3·57
Field (mowing) soil,	C^{40}	H^{14}	O^{14}	+2 "	60·11	5·41	27·52	6·96
Oak plantation soil,	C^{40}	H^{17}	O^{17}	+1 "	58·98	4·83	32·77	3·41
Proteine humic acid,	C^{40}	H^{12}	O^{12}	. . . .	64·67	4·32	31·01	. . .

The salts of ulmic and humic acid from these varied sources, have, dried at 140 degrees Fahrenheit, the following composition, viz:

		Carbon.	Hydrog.	Oxyg.	Nitrog.
Ulmate of ammonia, the acid from sugar	$C^{40}\ H^{14}\ O^{12}+am.$	64·75	5·06	26·92	3·97
Humate of ammonia, the acid from sugar	$C^{40}\ H^{12}\ O^{12}+am.$	64·58	4·22	27·46	3·74
Humate of ammonia, from protein,	$C^{40}\ H^{12}\ O^{12}+am.$	64·58	4·22	27·46	3·74
Ulmate of ammonia, from peat,	$C^{40}\ H^{14}\ O^{12}+am+2\,aq.$	61·43	4·92	30·61	3·04
Humate of ammonia, from peat,	$C^{40}\ H^{12}\ O^{12}+am+3\,aq.$	60·13	4·74	31·55	3·61
Ulmate of ammonia—willow,	$C^{40}\ H^{16}\ O^{16}+am.$	75·08	5·83	14·73	4·35

These are beautiful and valuable results. Executed by one of the great masters in organic analysis, they show a wonderful coincidence between the artificial and natural products. This has a direct connexion with agriculture. The source of the nitrogen of plants, depends upon these compounds of ammonia with the geine of soil. The composition of that substance shows, that by making it soluble, the farmer commands the same beneficial effects, which may be produced by nitre. But the researches of Mulder do not terminate with the analyses. He has examined the compounds which these forms of geine produce with other acids, particularly with muriatic and nitric. The compound of nitric and humic acid, is called nitro-humic; ulmin and ulmic, humin and humic acid, are decomposed by weak nitric acid. They are converted by gentle heat, immediately into a rust colored powder, and by prolonged action evolve oxalic and formic acids and nitrate of ammonia. Nitro-humic acid, the rusty brown powder, above, is soluble in water. Alkalies evolve ammonia from it. Its analysis affords—

C^{48} H^{16} O^{26} N^2 : or per cent.

Carbon.	*Hydrogen.*	*Oxygen.*	*Nitrogen.*
55·43	3·49	38·10	2.98.

It is highly probable, that this product is connected with the action of nitrates, or saltpetre in agriculture. All these products, observes Berzelius, are connected by an unknown thread. These black and almost insoluble acids, have a very weak saturating power, in comparison with their oxygen. This last exceeds that of the base, by 10, 12, or 14 times. Hence, Berzelius suggests, that all these organic acids may have a composition, anal-

ogous to sulpho-benzoic acid. This last is composed of benzoin and sulphuric acid, which determines the saturating power of sulphobenzoic acid. Hence if these forms of geine, are united to an organic acid, which acts like the acid in sulpho-benzoic, they may have an analogous composition.

Notwithstanding the objections raised by Berzelius, founded upon a want of correspondence between the oxygen and saturating power of these forms of geine, they are probably, modifications of one principle, differing not so much in their physical properties, as do fibrine, albumine, and caseine, or flesh, white of egg, and curd of milk. These are identical in composition, modifications of a common principle to which the name, proteine, is given by Mulder, its discoverer. It is not among the least curious of his results, that proteine is, by weak acids, changed into humate of ammonia, its acid being perfectly identical with that from sugar. In 1838, Prof. Hitchcock, in his report, published the following extract from one of the author's letters, when speaking of geine as the product chiefly of vegetable matter, it was added: "Animal substances afford a similar product, containing nitrogen." The author supposed at that time, that the nitrogen in geine was of animal origin; but since, it has been proved, that proteine is equally derived from vegetables and animals, the results of its decomposition by Mulder, leave no doubt, that the proteine of vegetables is the source of the ammoniacal compounds of geine, found in soil. That neither Mulder nor Berzelius, have the slightest doubt, that these ammoniacal compounds, are wholly distinct from crenic and apocrenic acid, is evident from the care of Mulder, to separate these last from the soil, and from the total silence of Berzelius,

respecting any mistake he may have been supposed to commit, by confounding geine with them.

New facts are wanting. The several organic principles of soil are probably oxides of a peculiar base or radical, to whose several modifications, the term geine, may like the term proteine, be applied. These modifications, may be found, even when fully known, to affect the practice of agriculture, as little, as did the true chemistry of oil and fat, affect soap making.

CHAPTER V.

OF THE MUTUAL ACTION OF THE ORGANIC AND INORGANIC ELEMENTS OF SOIL.

128. In agriculture, little and seemingly unimportant discoveries are valuable. Nothing is to be despised, which may lead to a rational and true theory of agriculture; this only can lead to successful practice. Practice, founded on sound principles, can be taught only by a knowledge of the manner how, the elements of soil affect each other, and vegetation. This knowledge cannot be obtained without the application of theoretical opinions. The opinions of merely scientific men, may be wholly theoretical; but what is science?

It is, says Davy, "refined common sense, the substitution of rational practice, for unsound prejudice."

In no department of human industry, is there so great a demand for the union of theory and practice, as in agriculture. The book farmer and the practical farmer, must now shake hands. They have been too long wrestling, and trying to get each other down, at arms' length, and now grappling in side-hug, they find the closer the embrace, the longer they stand. So it should be, theory and practice should mutually support each other.

129. The theoretical and the practical farmer aim at one common object. The latter is employing certain means to effect certain ends; the former unfolds the laws of nature, which limit and control the operations which are performed to effect that end. Theory may teach a rational and successful practice; this last may lead to a rational theory. But without a knowledge of the elements of soil, and of their mutual action, which is to be learned from chemistry only, the practical application of science to agriculture, is but the dream of enthusiasts.

130. How do the elements of soil act? The answer involves two important considerations. 1st. The mutual chemical action of the elements of soil, their organic and inorganic parts on each other; and 2d. This action, as influenced and modified, by the presence of living, growing plants.

131. The elements of soil, are silicates, salts and geine. The silicates, as such, have no tendency to react on each other. These are gradually decomposed by the action of the air. The great agent in this action is its carbonic acid, which gradually combines with the alkaline base of the silicates, and the potash, and soda, are converted into soluble salts, while the silex and alumina remain.

132. The result of this action is, that the land becomes gradually more clayey and tenacious; while the alkaline bases, carried away by drainage or filtration, enter brooks and rivers, and are finally found in sea water. The potash of the ocean, arises from the decomposition of rocks and soil. This action though very marked on felspar, is comparatively nothing except on the naked and exposed surface of rocks. Soil suffers but little from this

cause. The silicates of soil may be considered as stationary.

133. If the class, salts, be now introduced, those only which act upon silicates by mutual decomposition are earthy carbonates. The silicic acid acts on the lime, forming silicate of lime, while the carbonic acid, now let loose, acts as such upon other silicates, and eliminates or frees the alkaline bases. Let it be supposed that there is silicate of alumina, that is clay, or silicate of potash and alumina in the soil. Let carbonate of lime, that is marble, and slacked lime, shells, &c., be added to the soil. The result is, that slowly but surely, chemical action takes place, the silicic acid pulling one way and the carbonic acid another, the lime is changed to silicate of lime, and the carbonic acid escapes, and now in its turn acts upon silicates as did carbonic acid of air. The alumina remains, the soil becomes more clayey. Thus sands by liming are amended.

134. This principle, of the action of carbonates, unravels the mysterious action of a vast variety of substances, which appear to be very inert and inefficient. It must be remembered, that the action of silicates and salts is alone under consideration, uninfluenced by the presence of geine or plants. That action in its simplest form constitutes the following, which may be laid down as the ninth principle of agricultural chemistry, CARBONIC ACID, AND THE CARBONATES, DECOMPOSE THE EARTHY, ALKALINE, AND METALLIC SILICATES OF SOIL.

135. The result is, that the potash, soda, lime, magnesia, alumina, and metallic oxides are set free, and where silicate of alumina exists, the soil becomes more clayey, while the carbonic acid again acts upon silicates of alkalies and forms carbonates of alkalies. A clue is thus given to the action of

peat ashes, or coal ashes in amending a sandy soil. These ashes act by their carbonate of lime as above stated, freeing the alkali of the silicate of potash.

136. Hitherto, the action of the inorganic elements has been explained, uninfluenced by the organic or geine. Referring to the properties of this element, it will be recollected, that this is soluble or insoluble, that it combines with alkalies, earths, and metals. This element exerts a twofold action. 1st. The geine combines with the potash, soda, lime, alumina, magnesia, which have been let loose by the action of carbonic acid, and of carbonates, and forms geic salts or geates, while the carbonic acid which may be let loose from any carbonate of lime, acting upon these geic salts, forms super-geates, which readily dissolve. It is thus evident, that geine exerts an important and powerful influence upon soil. It is the agent, prepared by nature, to dissolve the earthy constituents of soil, rendering them so soluble, that they become fit for food, or constituents of plants.

2d. The free alkalies, produced as has been described by the influence of carbonic acid, and carbonates act on geine. They render this soluble. The curious and important fact, that a small quantity of alkali, renders an indefinite quantity of geine soluble, has been noticed (117); and it may now be added, that probably all the alkaline earths, and oxide of iron and manganese possess this power of converting vegetable fibre into geine. This effect has long been known to be produced by potash and lime. These hasten decay; and next in power to lime, in this singular process, is alumina, then oxide of iron, in passing from a lower to a higher state of oxidation.

137. This remarkable process, this power, ener-

gy, function, influence, property, called by whatsoever name it may be, which is thus exerted, by the elements of silicates upon vegetable fibre, and insoluble geine; and the power of developing acid properties in that principle, is intimately connected with the action of growing plants upon soil. The joint effect of organic and inorganic elements of soil and plants, may be better understood by adverting to the probable cause of this property of earths, alkalies and oxides; though in the present state of science this cause may be apprehended only by giving it a name, which, while it arranges many facts under one view only, hides as deep, the source of this classification. The cause of this effect, of alkalies, upon geine, is to be sought in that power, which has been denominated catalysis, and which the French designate as the action of presence. That is, the mere presence of a body, influences the nature of a second body, so as wholly to change its properties. It causes the elements of organic compounds to enter into new arrangements, by which they produce a totally different substance. The catalytic body, the present body, the changing body itself, suffers no change, except, perhaps, in some cases of ferments, whose activity depends upon their being in a state of decomposition, while the changed body loses nothing of its substance. It often gains oxygen and hydrogen, or the elements of water. For example, starch is converted into sugar by oil of vitriol. The acid suffers no change. It acts by catalysis, and converts the starch to sugar, simply by the addition of water, or its elements. So the peculiar principle found near the eye of the potato, converts starch first into gum, called dextrine, and then converts this into sugar of starch. So malt, by its gluten, converts starch in-

to sugar in the process of brewing beer. But the effect of this action, may not be confined to organic compounds only. It has lately been extended, by an acute German chemist, to all chemical changes; and it has been maintained that all chemical decomposition takes place in obedience only to a third substance, acting by its presence. Hence, this extension of the principle, will allow the decomposition of the mineral elements of soil, to be attributed to the catalytic action of the plant.

138. Having considered the action of the organic and inorganic elements of soil upon each other, it is seen, that though great, this action would be but very little, in centuries. The geine itself, would be dissipated in air, were it not that by this provision, it is combined with the earthy part of the soil, and there retained for the use of plants, which may grow near it.

139. Let plants be grown in the soil, whose action has been considered. This introduces life into the process, and it gives life to all around it. It is not pretended to explain what the action of life is. It has many relations with chemical processes. By the refined chemistry of the present day, many products are formed, which have been usually, and in fact, are now considered products of living action only; the peculiar product of life, urea, is formed artificially; so of other products, and out of carbon, nitrogen, and water, may be formed as many, and as complex products as are ever elaborated by a living process; yet, life is not a chemical process, and were it attempted to explain how, out of the four simple elements, carbon, hydrogen, oxygen, and nitrogen, all the variety of vegetable products are formed, it might be said that life is a catalytic power. The vital principle by its pres-

ence, impresses the same power on the food we take, that the peculiar principle in malt and in potato, called diastase, impresses on starch. It merely by its presence, gives to the elements power to enter into new combinations, and then these combinations occur in obedience only to the well known, established, eternal laws of chemical affinity.

140. So too, the presence of a growing plant, of the root, of a seed, where life is, impresses, on the soil, both on the organic and inorganic elements, power to enter into new arrangements. The soil, then, is not external to the plants; so far as life is concerned, it is as much internal as if the plant had a mouth and stomach, through, and into which the soil might be fed.

141. Call this power life, electricity, galvanism, or by any other name, still the great fact, that the mere presence of a living, growing plant in soil, in one year effects a greater amount of its decomposition, than all atmospheric influences, in many years, is one of the very highest interest, in a practical view. It is, perhaps, of more value than all the other actions which have been considered.

142. It is this decomposing action of living plants, on the inorganic elements of soil, which affords a reasonable explanation of the action of salts in agriculture. The catalytic power of life dissociates the elements of salts. They enter into new combinations. The base and the acid, are separated by the action of the living plant.

143. On no subject in agriculture, are opinions more divided, than on the manner, how salts or mineral manures act. Their amount in soil is small. That is soon exhausted. They cannot be artificially supplied, in excess, without inducing very serious injury, and in fact, often produce bar-

renness; yet are often decidedly beneficial. It is not less difficult to account for the good, than for bad effects of salts. Among all the variety of substances acting as salts, a distinct theory is generally framed and adopted for each. If any attempt has been made to arrange all the facts relating to this subject, it has ended in this that they are stimulants. They are to the plants, what condiments are to the food of man. This may do very well as an illustration, and it has been elsewhere said, that "the soil is the plate, the geine the food, the salt the seasoning."

144. This leads to no practical result, except it be this, that if salts are seasoning, like the seasoning of our food, they must be used sparingly. Some general law is wanting, which shall at once, account for the effects of salts, and while it points out how so very minute a portion as the four-hundredth part of one per cent. of the soil produces unquestionably good effects, one per cent. will be injurious. Some general principle is wanted, which will enable the farmer to say what the action of a salt will be; and whether he may apply one, or less than one per cent. of it, without risking his crop.

145. Such a general principle, can be deduced from the known chemical action of the elements of soil, aided by the living plants, upon each other. It is this tenth principle of agricultural chemistry, THE BASE OF ALL SALTS, ACTS EVER THE SAME IN AGRICULTURE. PECULIARITY OF ACTION DEPENDS ON THE ACID OF THE SALT.

146. Forget, reader, all other principles which have been presented to you. Banish from your mind, if you will, all that has been said, on the origin and nature of soil. Put it down, all, all to the

account of book farming. Let it be branded all as theory, and that too as the worst of theories, theory fruitless, a goodly blossom bearing no fruit, a Dead Sea apple ; but do not condemn the principle now enunciated. Let that stand alone, by itself, for itself. In all its length and breadth, it is the great practical principle of agricultural chemistry. It opens veins, rich in results, more precious than mines of gold.

147. The action of salts in agriculture, is to be regarded in a twofold light. First, a large proportion of salts is found in plants, composed of alkalies and alkaline bases of earths, united to a mineral acid, such as sulphuric, muriatic, phosphoric. These salts are taken up by the roots of plants when dissolved in water, and thus form a constituent of vegetables. Secondly, a large quantity of alkali and alkaline earths, is united in plants, with a vegetable acid. In this case, the salts of the soil, have been decomposed by the living plant. What is the consequence ? The base, if alkali, lime, alumina, magnesia, iron, acts upon geine, rendering that soluble, and it is then taken up as such, or it forms an alkaline or earthy, or metallic geate, which entering the plant as such, is there decomposed by the vegetable acid produced in the living plant ; while the acid of the salt thus let loose in the soil, acting on the silicates, forms new salts, which in their turn, play a similar part to that produced by the original salt.

148. The effect of this action of salts is, that they continually reproduce themselves. The effect may be illustrated by yeast, which added to dough, begets a new portion of the fermenting principle, which again added to new dough, still begets new leaven, and this without end. It is not to be under-

stood, from this illustration, that the action of salts is fermentation.

149. But let this action be farther illustrated; suppose there is added a salt, composed of muriatic acid and soda, that is common salt, to the soil. By the action of the living plant, this is decomposed. Its soda or base, then acts on geine. If this has been long in an insoluble, and perfectly useless condition, it is now rendered soluble, and hence supplies plants with food. A very marked and decided effect is perceived from applying a small quantity per acre, of a salt, which certainly of itself, contains no nutriment for plants.

150. The effects here produced, may be due to the small quantity of alkali, acting on an indefinite quantity of geine; but the effect so often observed, of the minute quantity of salts, say one-hundredth of one per cent. of the soil, seems hardly compatible with the explanation. So far as it goes, this is its action; but very probably the quantity of alkali in the salt sown, is taken up as a geic salt, and immediately carried into the plants. The base then is withdrawn, yet the action continues. It continues through the whole time the fruit is forming. Some other source, therefore, of the permanence of this action must be sought. That is due to the acid constituent of the salt. That, when the plant decomposed the salts, was let loose and now acts on the silicates of the soil. It decomposes these, uniting first with the alkalies, and thus reproducing itself. It is again decomposed by the growing plant. The same round of action continues. Suppose all this had been witnessed on a worn out, almost barren field. It is concluded at once, that there is some peculiar virtue in the salt applied, that it is of itself food, or manure; whereas the whole action is

in obedience to a general law applicable to all salts.

151. Suppose plaster or gypsum has been applied; the effects of a bushel of plaster per acre, or even the one four-hundredth part of one per cent. of the soil produces effects on alluvial land, which show its good results, as far as eye can reach. It seems almost incredible, that so minute a portion of a mineral can act at all, yet how beautifully is this result explained, by the principle, that plants decompose, first, this salt; the lime, for plaster is a sulphate of lime, then acts on geine, which is thus rendered soluble; while the acid, the oil of vitriol or sulphuric acid, immediately acts on silicates. If silicates of alkali exist in the soil, we have now changed sulphate of lime for an alkaline sulphate, and if silicate of lime is also present, the potash or alkali, having been exhausted, plaster of Paris is formed anew. So long as there is in the soil organic matter, this action continues, and will continue till the plant has gradually withdrawn for its own use, the acid of the salt which was introduced.

152. Fertility depends wholly on salts and geine. Without the last there is no fruit formed; without the salts the geine is locked up, is insoluble. Consider now the application of this principle, that the base of the salts acts always in one uniform way, its action is wholly upon geine; that the acid of salts, acts upon silicates. Apply this principle to all mineral manures, as they are called. They are all connected by one common mode of action of their base. There is no speculation, there is no mystery, as to the mode how they act. The effect produced by such wonderfully minute quantities is no longer astonishing. It is no more wonderful than that leaven should make dough rise; it is even less mysterious.

153. Apply this principle to acids, which have sometimes been used. Sprinkle a small portion of oil of vitriol on the soil; supposing no free base present, the silicates are decomposed by the oil of vitriol, and sulphates of alkalies, and alkaline earths are formed. These new formed salts are, in their turn, decomposed by the living plants; and the action on geine commences, as has been explained.

154. Consider how salts and geine are linked. It is at once seen how essential to the action of salts is the presence of organic matter, or geine in the soil. It is the want of a principle like that which has been stated, which has led to a waste of time and money, in applying mineral manures, to worn out and barren soil. Whereas, the principle (145) leads to the application of both salts and geine. The salts alone, would be useless. Their first effect in either case, would be the same on silicates; but with geine, this action, like fermentation, goes on, begetting new salts; without it, this action ceases after the first chemical changes have occurred. In the first case, it goes on. In the second, it stops.

155. Salts without geine, act only on silicates of the soil. If now, these silicates contain any portion of aqueous rock, (11) they usually contain also, distinct traces of organic matter. This matter is due for the most part, to the geine, held in solution in the water, from which the rocks were deposited. It is certainly within the bounds, not only of a chemical possibility, but of a high degree of probability, that the carbon under the influence of growing plants, may unite with oxygen or hydrogen, that is, with the elements of water, and form thus food for plants. Hence, on such soil, the mere application of salts, or of mineral manures, yea, and does pro-

duce marked and wonderful effects. This would be the effect of salts, applied to soil produced by the decomposition of slate ; even gneiss soil, which occurs occasionally in extensive patches, would be benefitted, but much less by such application. But such soil forms an exception, both to the general law, which has been stated, of the uniformity of mineral composition, and to the necessity of applying salts and geine in conjunction. These remarks may explain a seemingly possible anomaly to the principle, that the base of all salts acts in one uniform manner upon geine, and that peculiarities of action depend on the acid of the salt. The effects of the first part of this proposition have been explained; the effect of the second, is now to be considered.

156. Perhaps no principle in agriculture, is better established than that an excess of any salt in the usual acceptation of that term, is a cause of barrenness. Yet it is quite as well established, that the quantity of different salts admits of some latitude ; and that some salts do produce better results than others. Referring to the acid constituents of these salts, it will be found that some acids are organic. They consist of hydrogen, carbon, oxygen, all which under the influence of the living plant, may be dissociated, and their element form geine. Other acids consist of oxygen and nitrogen, essential constituents of plants ; others consist of chlorine; others of sulphur and oxygen, and others of carbon and oxygen. In other words, the acids are composed of elements, which form food for plants, or of elements which enter in a small proportion only, into the composition of plants.

157. In the first case, the salts admit of a larger quantity being applied, than in the second. By the

first, are fed, by the second, plants are poisoned; for the base of all salts acting, as has been explained, the acid is eliminated; if this is set free in large quantities, and its elements can be taken up and converted by the plant, well, good effects follow; if on the other hand, the elements of the acid are such as the plant, like poison on the animal economy.

158. Let salts be divided into two classes, on this principle of the peculiarity of action depending upon the acid of the salts, the first nourishes, the second poisons plants. The first class contains, first, carbonates—second, nitrates—third, phosphates.

159. The action of the first class is to be studied under its three divisions. First, the carbonates. These include a very large portion of all salts used in agriculture. It includes, limestone, (14) marble, old mortar, shells, shell marl. In all these cases, the base or lime, let loose by the action of the living plant, acts at once, as caustic lime upon insoluble geine, and unconverted vegetable fibre, changing these into soluble vegetable food; while the carbonic acid acts immediately upon silicates, decomposing these, and upon the geates in the soil, converting these into super-geates. Carbonates of alkalies, as ashes, &c., act at once. They are soluble, their alkali acts immediately upon the geine. Their carbonic acid acts upon silicates and geine. Immediate and decided good effects follow their application; while carbonate of lime acts slower. It often requires many years to bring out the good effects of carbonate of lime, and though ultimately these effects, it is believed, have never failed of being witnessed; yet so slowly, that its use has been often condemned. The principle which is here

discussed, may account for this apparent discrepancy. Suppose a barren, worn out, exhausted soil, containing yet, a large portion of insoluble geine, and decayed vegetable matter, between the state of wood and insoluble geine, or even a portion of undecayed, dead wood. It seems too unpromising to give it manure; little of that is to be spared, and that is bestowed upon better land. If this is in a country where lime is cheap, that is purchased, and freely applied, as it is in England, at the rate of about a cask to the rod. Even in this case no change is produced, the soil is as unproductive as ever. The experiment has failed, and is charged to book farming.

160. The properties of lime, and geine, are here to be remembered. Lime in excess, renders geine insoluble, granting it to have been in a soluble state. Lime changes vegetable fibre into soluble geine, but being applied in excess it forms an insoluble salt. Now by the supposition, there was no great excess of vegetable matter, and the lime, rendering only a small portion of that soluble, is itself then, always in excess, and though it converts, it at the same time locks up that geine which it had converted. The reasoning will hold good, whether a cask to the acre, or a cask to the rod, has been applied.

161. The lime has been perhaps, in a caustic state, fresh from the kiln, and as soon as it falls into powder it is spread and covered in. It is greedy of carbonic acid, so long as it remains caustic, it absorbs this gas, and slowly becomes carbonate of lime. It is now like shell marl, clam, oyster and muscle shells. The mode of reasoning applies to all these forms. Slowly, but surely, it may not be for some years, a gradual improvement in the lim-

ed soil of the exhausted field, is perceived. The carbonate of lime begins to act on the silicates; and the alkalies of the silicates are eliminated. These solve or decompose the geine and geates, which the lime had locked up; at the same time the silicic acid acts on the carbonate of lime, volumes of carbonic acid gas are let loose. The carbonic acid itself reacts on silicates, eliminating a fresh portion of alkali, and upon the geates, converting these into super-geates. A round of changes goes on, till perhaps, every particle of vegetable food is withdrawn; crops are no longer raised. Having witnessed, though slow to believe it, good effects from liming, the farmer again applies it to the exhausted field; but no good effects can now follow, unless manure or decayed vegetable matter is also applied. This may be furnished in two ways, either artificial or naturally, that is by allowing the scanty crop of all sorts of weeds, grass, mullein, &c. to decay on the soil where it grew. But this subject will be considered in another place.

162. It has been attempted to show how the contradictory and anomalous effects of lime are explicable, on the principle (145); and here the general theory of the action of lime may be adverted to, much of which has been anticipated. Lime is a general term, it includes all forms of calcareous matter. It is the lime, the base of the salts which acts, and that always as lime, no matter how it is applied; whether as marble, as marl, shells, air slacked lime, bones or plaster. In a restricted and usual acceptation of the term, lime refers only to that which has been burned, or stone lime. Its action is threefold, each distinct, first, as a neutralizer—secondly, a decomposer—thirdly, a converter.

1st. Wherever free acids exist in soil, lime acts

as a neutralizer. It has been asserted, on undoubted authority, that occasionally free phosphoric, muriatic, geic, acetic and malic acids exist in soil.

2d. Soil may contain abundant geates, particularly geate of alumina, the least of all demanded by plants. Long formed and sun-baked, they are scarcely acted on by rain or dew, and are almost useless. Here, lime, by decomposing these earthy and metallic geates, forms a combination which in its nascent state, is readily dissolved. If the carbonate of lime, acts better than the hydrate, it is because, following a well known law, double decomposition is easier than single. If any acid geine exists in the soil, or any free acids, carbonic acid is then liberated, it acts on the geate of lime, supergeates result, and these are easily soluble.

3d. The great use of lime is as a converter, turning solid and insoluble-geine, even solid vegetable fibre into soluble vegetable food. Here is the point, where philosophy seems to give the choice, to refer this action to one of the numerous cases of catalytic change, which are every day becoming more and more familiar; or to explain the whole process by referring it to saponification. This word is used as conveying at once what is meant, but it is not meant to say that the product of lime and vegetable matter is soap. The action of lime on geine, may be similar to its action on oil and fat. It is well established, that animal and vegetable oils and fats, are converted into acids, by the action of alkalies, earths, oxides, and even by vegetable fibre itself. The general law is, that whenever a substance, capable of uniting with the acid of fat or oil, is placed in contact with fat or oil, it determines the production of acid. Now it has been shown, that alkali produces a similar change on geine, it

developes acid properties. If alkali has converted vegetable oil and geine into acid, it is a reason why a similar action may be produced by all those substances which act thus on oil. Hence lime, earths, and metallic oxides, convert geine into acid; as fast as this takes place, so fast it becomes soluble. Then too, the long action of air on insoluble geine rendering it soluble, is it not analogous to the action of air on oils? Both evolve in this case, vast volumes of carbonic acid, the oil becomes gelatinous and soluble in alkali, does not a similar change occur in geine? It is possible that during the action of lime on geine, a soluble substance may be produced, bearing the same relation to this process that glycerine does to saponification. These views need to be followed out experimentally, and may be possibly hereafter considered.

163. In the acid soil, lime acts to eliminate carbonic acid, which then acts on silicates and geine, as has been explained. All fat acids or fats and oils, act in the same way upon silicates, partly by their own acid properties, and partly by the evolution of carbonic acid gas, which is evolved during their conversion into the acid state. The quantity of carbonate of lime which may be applied is unlimited, and the quantity of alkali depends on the presence of insoluble geine. The more abundant is the last, the more freely may alkalies be applied. The carbonates include ashes of all kinds, and agriculturally viewed, all kinds of lime, for the quick soon becomes mild. The value of ashes in agriculture, depends upon its being a combination of salts derived from plants, all of which have a powerful and decidedly beneficial effect. The question is often asked, what is the relative value of spent

or leached and unleached ashes. It may be answered by reference to the analysis of ashes.

Burning reduces these constituents to two classes, ashes and volatile salts. The last are found in soot. The ashes are formed of salts and silicates. These vary in quantity and quality, not only in different plants, but, as is well known, in different parts of the same plant. Let us take oak, beech, basswood, birch, as the types of the composition of hard wood ashes; yellow pine,—(*pinus abies*)—as the type of soft wood ashes; and wheat straw as the type of the ashes of the grasses.

The average quantity of ashes from 100 parts of dry oak, beech, birch, &c., is 2·87. Ashes are divided by the simple process of leaching, into two parts, soluble and insoluble in water. 100 parts of hard wood ashes thus afford—soluble, 13·57; insoluble, 86·43.

100 *parts of the soluble contain:*

Carbonic acid,	22·70.
Sulphuric acid,	6·43.
Muriatic acid,	1·82.
Silex,	·95.
Potash and soda,	67·96.
	99·86.

100 *parts of the insoluble contain:*

Carbonic acid,	35·80.
Phosphoric acid,	3·40.
Silex,	4·25.
Oxide of iron,	·52.
Oxide of manganese,	2·15.
Magnesia,	3·55.
Lime,	35·80.

Pine,—(*pinus abies*)—100 parts of dry wood afford only ·83 lb.; of which 100 parts afford soluble, 50; insoluble, 50.

100 *parts of the soluble contain:*

Carbonic acid,	13·50.
Sulphuric acid,	6·90.
Silex,	2·
Potash and soda,	69·70.
Water,	7·90.
	100·

100 *parts of the insoluble contain:*

Carbonic acid,	21·50.
Phosphoric acid,	1.80.
Silex,	13·
Magnesia,	8·70.
Oxide of iron,	22·30.
Oxide of manganese,	5·50.
Lime,	27·20.
	100·

Wheat straw—100 parts yield 4·40 lbs. of ashes; 100 parts of which afford, soluble, 19; insoluble, 81.

100 *parts of the soluble contain:*

Sulphuric acid,	0·2.
Muriatic acid,	13·
Silex,	35·6.
Potash and soda,	50·

100 *parts of the insoluble contain:*

Phosphoric acid,	1·20.
Silex,	75·
Oxide of iron,	2·50.
Lime,	5·80.
Charcoal,	15·50.

Peat ashes abound in carbonate, sulphate, and especially phosphate of lime. Free alkali may be always traced in peat ashes; but alkali exists in it, rather as silicate, as in leached ashes. Anthracite coal ashes contain carbonate of lime, alumina, and oxide of iron. It is good, so far as these abound.

The above are calculated on the analyses of Bertheir, who has detected soda in the ashes of many plants. The elements are stated singly; because we have thus at one view, the amount of each, and, it is the base chiefly which acts. The agricultural value of ashes may be determined by reference to these tables. In what state these elements may be combined in plants, we can only determine theoretically. Thus, the phosphoric acid, by its affinities, would be united in the hard woods as above, with the lime and iron, forming in each 100 parts of the insoluble portion of ashes, phosphate of lime, 5·40; phosphate of iron, 1·86.

The composition of the insoluble part of ashes gives nearly the constituents of leached ashes. If the soap-boiler's process was as perfect as that which the chemist employs, still his leached ashes would show more lime, than the above tables, because he always employs a portion of lime to make his ley caustic. This is a variable portion; whatever it is, it adds so much to the value of the leached ashes. Besides the soap-maker always leaves a portion of alkali, which is combined with the silex. Exposure to air decomposes this, and then the alkali can be extracted by water. This is one great source of the active power of leached ashes.

164. A bushel of good ashes contains about 5 1-2 lbs. of real potash. In leaching ashes, generally about one peck of lime is added to each bushel of ashes, and as it loses no bulk during the operation,

a cord of leached ashes contains about the following proportions, allowing the usual proportion to be leached out, or 4 1-2 lbs. perbushel :—

Phosphoric acid, ...	117 lbs.
Silex, ...	146 "
Oxide of iron, ...	17 "
" of manganese, ...	51 "
Magnesia, ...	119 "
Carbonate of lime, including that added in leaching, ...	3072 "
Potash combined with silica, ...	50 "

Spent ashes, therefore, belong to the class of carbonates.

165. It may be here remarked in relation to silicate of potash, that this substance forms a greater part of the residuum produced in the conversion of pot into pearl ashes, for the purposes of glass manufactures, &c. This residuum has been used with the most signal success, when mixed in the proportion of a barrel of this material, with ten horse-cart loads of soil alone.—(See Colman's fourth Report, page 344.)—The silicate of potash, depending entirely for its conversion into carbonate of potash, is properly considered in the class of carbonates.

166. The second class of salts, belonging to the first division, or nourishers, are the nitrates, including not only saltpetre, both East India and South American, or nitrate of potash and nitrate of soda, but also all composts of lime, alkali, and animal matter. These produce ammonia, which, without the lime would act on geine, and render that soluble. Ammonia, by the mere act of presence, hastens decay; but without the influence of lime ammonia is changed to a nitrate of ammonia,

167. Thus in a compost of animal matter without alkaline bases, not only has not all the geine been rendered as soluble, as is usually supposed, by the action of ammonia, before its full action has occurred on the organic matter, to be converted into a nitrate of that base. But if the lime exceeds that which the nitric acid can saturate, then the soluble geine is seized upon, and becomes inert. Nitrates act under the influence of the growing plant, the base let loose acts on geine, the acid is decomposed, and nitrogen given up to the plant, and it becomes one of their essential elements. The elements of nitrate of ammonia are all taken up both acid and base. If there are any salts which can be called vegetable food, they are the nitrates. The organic constituents of plants, are hydrogen, and oxygen, carbon and nitrogen. The two first form water; the two middle carbonic acid, the first and last, ammonia. Water, ammonia, and carbonic acid then, or their elements, compose the organic part of all plants. Water and carbon exist in the first division, and nitrogen in the second division of geine, which thus contains the elements of water, ammonia and carbonic acid, or the whole food of plants. The nitrogen, also, exists in the air. It forms 80 per cent. of it. In this state it cannot be assimilated by the plant till that has put forth its leaves. Its only source for the roots and for the germinating seed, is that arising, either from the geine, or from ammonia evolved by the fermenting dung, or from nitrates. In either case, whether the nitrogen arises from the geine or from the nitrates, decomposition takes place, by the action of the living plant.

168. Under this view, nitre is found to be one of the most active of salts; yet bland and beneficial in all its actions. Nitre is alkali, and acid com-

posed of one part of nitrogen to five of oxygen. The plant decomposes these. The disposition of the alkali or of the base, has been already considered. The disposition of the alkali or of the base, has been already considered. What becomes of its acid? That too, slowly is decomposed. What becomes of its elements? The one part of nitrogen is taken up by the living plant, or it may, under the combined influences to which it is now subjected, be in part reconverted, into ammonia by the hydrogen of the geine, and so act on that, as alkali. What becomes of its five parts of oxygen? The answer is full of the highest interest. It is a master's key, unlocking the chambers of mystery. The oxygen acts, first on the geine of the soil, and secondly on the silicates. And first on geine; let it be supposed that this is wholly insoluble, perfectly inert. It has been already said, that air converts this into soluble geine. This action depends on the oxygen of the air acting on the carbon, by which carbonic acid is formed; the geine is thus rendered soluble, while the carbonic acid escaping, acts on the silicates of the soil, and these are thus decomposed. There is no mystery now in the action of saltpetre or nitrates of alkalies. The immediate effects are due, to the liberated alkali, acting on the geine. Its permanent effects, for experience has proved permanency of effect, peculiarly due to nitrates, is owing to the liberation of an immense dose of oxygen which is produced from the gradual decomposition of the acid. Now the insoluble geine condenses this in its pores, like charcoal. This condensation like that of gas by charcoal, produces heat; it is like fermenting manure, while the condensed oxygen acts slowly on the geine, forming carbonic acid. It has upon the geine, buried in the

soil, the same effect that tillage would have, rendering it soluble, with this additional advantage—that its carbonic acid instead of escaping acts on the silicates. New portions of alkali are thus liberated, supplying for years that which was first applied, as a part of saltpetre. The nitrates then, hold the very first place among salts, in agriculture.

169. Thirdly, phosphates—this includes bones, horn, nails, hoofs, and claws, and a large portion of the salts found in the liquid excretions of animals. These act much like nitre, the acid forming a constituent of the plants. It is not probable that the acid in this class is decomposed. It has not yet been proved that carbonates and nitrates exist already formed except in a very few plants. The quantity of salts which may be applied, will be greatest in the carbonates, next in the nitrates, and thirdly in the phosphates. The quantity of any salt which may be used will, after the largest amount, which can be safely employed has been ascertained, depend upon the farmer's ability to produce it. Carbonate of lime, may be used to any extent, according to the farmer's idea of its value. Carbonates of alkali may be used with benefit. The largest quantity which has been known to be used without injury, has been 53 bushels of ashes per acre, which are equal to 240 lbs. of potash. The quantity of the carbonates of alkali, which may be used, will be stated more fully hereafter. It is not the object of this work, to state quantities to be used, so much as to point out the principles on which salts act. The quantities used, must be determined by experiment, and perhaps when the largest amount, which has been stated, is taken for a new starting point, the ultimate quantity,

will be found limited only by the geine in the soil, or applied in conjunction with the salt.

170. If we now turn to the other division of salts, the poisons, that is, those whose acid forms but a small portion of the elements of plants, we find two classes: First, sulphates, as plaster, copperas, Glauber's salts, all of which in small quantities, are beneficial. An explanation, which attributes the action of sulphate of lime or plaster, to its power of decomposing and fixing in soil, carbonate of ammonia ought to show, 1st. the actual presence of that salt in air; 2d. that sulphate of ammonia is not decomposed by the resulting carbonate of lime in the cold; 3d. that common salt, would in equivalent quantity with plaster, produce equally good effects. It never has, and therefore this explanation is not correct.

Secondly, Muriates or chlorides, as they are strictly called, as common salt, muriate of lime, bittern, spent ley from soap-works. Common salt has been found beneficial when applied at the rate of 30 bushels per acre; and at 14 bushels per acre, was found to produce effect, next best to 53 bushels of ashes per acre, but quick lime at 26 bushels per acre on the same land, produced no good result.

171. In all this action of salts, it is seen that the presence of life seems almost essential. Whatever the vital principle may be, it may be best represented as analogous to electricity and galvanism. In this point of view, the salts present themselves in a new relation. In a relation, in which alone, they may be said to be stimulants or excitants. Plants and soil act, it may be supposed, for illustration, by forming galvanic batteries, or piles with each other. The most active element in the pile, is the growing plant. It is an acknowledged fact, that chemical

action, if not the source is ever attended by electrical effects. An acid, in contact with an alkali, or metal, always produces chemical action; but the silicates of the soil, are already combinations of acid and metals ; hence as such, they have no tendency to act on each other. If there be added to these a salt or an acid, chemical action, decomposition begins. The electricity is, we may say, excited by salts—they are in this sense, and in no other, excitants or stimulants. The very first act of vegetation, the germination of seeds, induces this electric action, this decomposition of the elements of soil. Germination produces carbonic acid, by decomposing water. This has been so abundantly proved, by late experiments in France, that it appears to be a good argument against the theory, that the only action of humus is, its production of carbonic acid, to supply the wants of the plant, before nature has clothed it with those organs of aspiration, the leaves, by which the carbonic acid is withdrawn from the air. It seems hardly probable that nature should require the presence of humus or geine, merely as a laboratory of carbonic acid, to supply the wants of the young plant. The very first act of life in a seed is to evolve carbonic acid, by its carbon combining with oxygen of air, and its second act is to decompose water. Its oxygen combines with the carbon of the seed, a single bean, produces many times its bulk of carbonic acid gas; and in the soil would surround itself with an atmosphere of carbonic acid. This evolved, begins its action upon the silicates. The living seed begins the electric action, and the plants exert and keep up this influence. Salts act in a similar way, but above all, over all, influencing all, is the living plant. This electric action induced, extends to un-

determined distances; hence there is a transfer, as is usual in all cases of galvanic decomposition, of substances remote from the plant, to its root, where they are taken up. It is not the potash and lime, &c., immediately in contact with the root, which alone supplies the plant, but under the galvanic influence, an undetermined portion of soil is decomposed. This decomposing agency of plants, wholly destroys all confidence in experiments, undertaken to prove that pure water alone, can nourish plants. The containing vessel, that is the vessel in which the experiment is made, is itself always decomposed. If to guard against an error, glass is used, it has already been shown, that this is only a combination of silicates, and these will be transferred from the glass to the plant.

CHAPTER VI.

MANURE.

172. THE true farmer, no less a sage than the ancient orator, who gave to action, the first, second, and third place in eloquence, will answer if it is asked him, what is his first requisite? Manure. What second? Manure. What third? Manure. These answers are to be united. Action and manure are the first and last requisites in agriculture, and in the attempt to show what is the last, and how it acts, will be offered every inducement to action.

173. Manures are compounds of geine and salts. They of course contain the whole elements of fertility. Having discussed the nature and mode of action of salts, and of geine, the way is prepared for the discussion of manures. The proportion in which these elements exist in manures is now to be examined.

174. The immense variety of substances, used and recommended for manures, would seem to render this subject both extensive and complicated. It is capable of simplification. Manures are generally considered and treated of, under the division of animal and vegetable. This common and ancient division, indicating little of the nature of manures, actually confounds those, whose elements are es-

sentially alike. Manures are to be divided by their elements, into three classes :—

1st. Those consisting chiefly of geine.

2d. Those consisting chiefly of salts.

3d. Mixed, or consisting of salts and geine.

175. This seems to be a rational and practical mode of classifying a vast amount of materials, and the explanation of their action in classes, is preferable to a specific account of each individual substance composing these classes.

176. By far the greater part of manures belongs to the third class. Such are all composts, all stable manure, and all the usual products of the cow-yard and hog-pen. In discussing therefore, this subject, there ought to be some starting point, some standard common measure of value, to which can be referred all manures, and by which their worth can be determined.

177. In selecting a manure for this purpose, if it can be ascertained, how much of geine, what, and in what proportion salts enter into its constitution; what gases it evolves, what chemical action it induces upon silicates, it will determine the relative value of all manures, they will approach or depart from the standard, in exact proportion to the geine and kind of salts they contain.

178. Manures then, are the elements of fertility. They contain, beside the inorganic salts, the organic elements of plants, oxygen, hydrogen, carbon, nitrogen. The quantity of ammonia which each manure can afford, will be in direct proportion to the quantity of nitrogen which each contains; and perhaps the only true and scientific view, which should be taken of manures, is that, which states their components not as compounds, but as simple elements; a statement which should give at a glance

the exact quantity of the four organic elements which enters into their composition. To a limited extent this can be done, and in the attempts to illustrate this subject, this mode of stating the value of manures, will be united with a more detailed account of their ingredients.

179. And first, for the choice of some substance which shall form the type of manures, and be considered the standard of value. Let it be pure, fresh fallen cow-dung, and what is its composition? Water, hay, and bile, with a few salts. The author has repeatedly analyzed this form of the food of plants, and it is found that the water is a very uniform quantity at all seasons and with various food. Others have found a few per cent. less than that which will be here stated; while some late and distinguished German chemists, have given results agreeing with this statement within a fraction of one per cent.

180. The proportions of organic matter and salts, and water, in 100 lbs. of cow-dung, are—

	Water,	83·60
Organic Matter.	Hay,	14·60
	Bile and resinous & biliary matter,	1·275
	Albumen,	·175
Salts.	Silica,	·14
	Sulphate of Potash,	·05
	Geate of Potash,	·07
	Muriate of Soda,	·08
	Phosphate of Lime,	·23
	Sulphate of Lime,	·12
	Carbonate of Lime,	·12
		99·86
	Loss,	0·14
		100·

181. 100 parts of cow-dung by Morin's analysis, consist of

Water,	70·
Vegetable fibre,	24·08
Green resin and fat acids,	1·52
Undecomposed biliary matter,	0·60
Peculiar extractive matter,	1.60
Albumen,	0·40
Biliary resin,	1·80
	100·00

182. 100 parts of cow-dung, by the analysis of M. Penot, in 1835, consist of

Water,	69·58
Bitter matter,	0·74
Sweet substance,	0·93
Chrophylle,	0·28
Albumen,	0·63
Muriate of soda,	0·08
Sulphate of potash,	0·05
Sulphate of lime,	0·25
Carbonate of lime,	0·24
Phosphate of lime,	0·46
Carbonate of iron,	0·09
Woody fibre,	26·39
Silica,	0·14
Loss,	0·14
	100·00

183. Other analyses have given a greater amount of water; and differ but little in that item from the experiments of the author. Truly this statement does not lead one to suppose, that a very good se-

lection has been made, in the choice of the standard of value for manure. Here is a substance, 83 1-2 per cent. of which is pure water. Let that be thrown out of the account; there are 14 per cent. of hay; this is very little altered, it seems only bruised and chopped, but it has lost some of its albumen, gum, &c. Now the last is that portion of nutriment, which the animal has extracted from the hay.

184. It is found that hay which has thus been passed through living organs, has its elements much less disposed to remain combined, or, in other words, decay, that species of fermentation which forms geine, takes place much more rapidly in the hay of cow dung, than in common hay. The catalysis of life, has impressed its power of disassociation on the hay of cow dung. The hay may therefore be considered geine.

In the same class may be included the biliary matter, deducting from this the green resin of hay associated with it, and there remains in 100 lbs of dung, only a small proportion of salts and biliary matter.

The albumen from its great tendency to spontaneous decomposition, may also be ranked as geine. It produces abundance of ammonia during decomposition, and probably is the great source of the evolution of that gas, during the fermentation of cow-dung. Its proportion is very small, being only about a sixth of one per cent.

185. Without violence to chemistry, the composition of cow-dung may be stated as follows:

Geine,	15·45
Salts,	0·95
Water,	83·60
	100·00

In 100 lbs. hardly 1-6 of any value in agriculture! Only about 1-6 of cow-dung is soluble geine. The insoluble is converted to soluble by the action of the evolved ammonia.

186. An important question here presents itself. How much ammonia will 100 lbs. of cow-dung produce? The ultimate analysis of this substance, that is, that analysis which gives the proportion of the organic elements, is the following:

In 100 *parts of cow-dung*—

Nitrogen,	·560
Carbon,	·204
Hydrogen,	·824
Oxygen,	4·818

187. From these data may be calculated how much ammonia will be formed; for one part of nitrogen unites with three parts of hydrogen to form ammonia, or in the atomic proportions by weight:

14 of nitrogen,
3 of hydrogen, which form
—
17 of real or pure ammonia.

100 parts of fresh fallen cow-dung will afford therefore, 0·614, or 5-8 of a pound of pure ammonia, or 2·13 lbs., or about 2 lbs. 2 oz. of carbonate of ammonia of the shops, called sal volatile or salts of hartshorn.

188. Cow-dung then, the type of manures, resolves itself into geine, free alkali, and salts. The salts, considering the nitrogen as carbonate of ammonia of the shops, will form about three per cent. of the weight of the dung; or a bushel of 86 lbs.

will contain, in round numbers, 2 1-2 lbs. of salts of ammonia, potash, soda and lime.

189. The cow, then, is the great manufacturer of salts and geine, and it is a question of the highest interest, what is the daily produce of her manufactory? In order to determine this, the following experiment was conducted with great care, at the barn connected with the print works of the Merrimack manufacturing company, in Lowell. A single cow, being only an average producer of the article in question, was selected from the 50 cows usually kept at the establishment. She was fed as usual, and as the other cows were. The food and water were accurately weighed for seven days. She consumed in this period,

Water,	612 lbs.
Potatoes,	87 "
Hay,	167 "
Total,	866 "

food and drink, and voided, free from her liquid evacuations, 599 lbs. of dung.

From the facts which have been now stated, it is evident, that one cow prepares, daily, from 24 lbs. of hay, and 12 lbs. of potatoes, about one bushel, or 85·57 lbs. of dung. This affords only 14 1-2 lbs. of solid manure, composed of hay so acted on by the digestive organs, as to form geine, when united with ammonia produced by putrefaction. One cow daily forms therefore—

12 lbs. geine,
1-5 " say 3 oz. of phosphate of lime,
1-10 " say 1 1-2 oz. of plaster of Paris,
1-10 " say 1 1-2 oz. of chalk.

Or per year:

4400 lbs. of geine,
17 " of bone dust,
37 " of plaster,
37 " of lime, marble, or chalk,
25 " of common salt,
15 " of sal enixen, or sulphate of potash:

These are equal to one cow, or a cord of green cow-dung, pure as dropped, would be formed, daily, by 108 cows. A cord of dung weighs 9,289 lbs., which ÷ 86 lbs. = 1 cow, = 108 cows. And one cow daily produces in excrements, salts of lime sufficient for half a bushel of corn.

190. Multiply the quantity produced by one cow, by the number of cows kept, and it may easily be calculated, how much salts and geine, are annually applied to soil, in this form. This is better done, than the estimate by cords or loads. The manure from one cow is a definite comprehensible quantity, and it may be expressed by saying, that one cow is spread per acre.

191. Estimating the nitrogen as ammonia, the yearly product of one cow is 155 lbs. of nitrogen equal to 188 lbs. of pure ammonia, or equal to 550 lbs. of carbonate of ammonia of the shops. A single cow, will therefore give annually, fed on hay and potatoes, 31,025 lbs. of dung, containing

4,400 lbs. of geine,
550 " of carbonate of ammonia,
71 " of bone dust,
37 " of plaster,
37 " of chalk,
24 " of common salt,
15 " of sulphate of potash.

192. It is perfectly evident from this view, that the main agricultural value depends on the ammonia or nitrogen, and the geine. The lime in its forms of salts, goes but little way towards this value, yet valuable, so far as they exist. It is evident from section 74, that the lime in the above salts of lime, the annual product of one cow, is sufficient to supply the grain and straw of a crop of wheat, of twenty bushels per acre, on three acres.

193. If these, then, are the elements of plants which are found in cow-dung, is it to the organic or the inorganic portion, that the enriching power is due? The great value of dung as a manure, has been supposed to be due to its animal matter. The common idea of animal matter includes substances which contain much nitrogen, but is it to the nitrogen, or to salts, that the chief value of manure is due? To the nitrogen, chiefest and first, and that too, as it exists in the albumenous portion of dung. The nitrogen of the hay contributes very little to the value of manure. The hay furnishes the geine, and probably all its nitrogen is employed in producing those forms of it, which contain that element, that is crenic and apocrenic acids. That it is the nitrogen of dung, only, the part not contained in the hay, which evolves ammonia, is evident; for if the nitrogen of the hay only, was the essential element of manure, then hay, which contains about one per cent. of nitrogen could supply its place; 50 pounds would be equal to 100 pounds of dung. It is well known that such effect is never produced by planting on hay.

194. It is not to the nitrogen only, in dung, to which can be referred the action of this manure. It depends on its other elements, salts and geine. The action of nitrogen is referred to its power of

forming ammonia, and this then acts in two ways. First, upon geine or the hay part; secondly, upon silicates. First, it is a powerful alkali. Now it has been shown that all alkaline earths convert insoluble, into soluble geine. Secondly, it is a well established fact, that the production of nitre, is not necessarily dependent on the presence of animal matter; but that, under the influence of porous materials, aided by alkalies or lime, the elements of air combine and form nitric acid and nitrates. This action is greatly assisted by ammonia, which acts by catalysis. The great use of the animal matter is to produce this alkali or ammonia. If no alkaline base is present, it becomes the source of the formation of nitrate of ammonia. This salt being decomposed by the living plant, its nitric acid acts on the silicates, and saltpetre or nitrate of potash is produced. The agency of this as a manure, has already been considered (167, 168.) The action, also, of other salts in dung, will be easily understood by reference to the fourth chapter.

195. There is still a powerful effect due to the geine, or to the hay in its conversion to that state. During this process, an immense quantity of carbonic acid is liberated. The decomposing action of this upon silicates of the soil, and the consequent liberation of their alkali, has also been explained, (133.) All these actions are to be remembered, in accounting for the action of cow-dung. The geine, salts, nitrogen, each acts—the geine has an action, the salts an action, the nitrogen an action. They all contribute to one end. Three substances, but one result, viz: Vegetation.

196. The nitrogen then, in dung, is that organic element, to which must be attributed its chief enriching quality. The nitrogen is the basis, both of

the production ammonia, and of the formation of nitrates. Hence, the quantity of nitrogen in manures, will form a very good element in the estimation of their value. Manures will be found rich, in proportion to their quantity of nitrogen, or their power of forming nitrates. This is the great and first cause of the enriching power of dung. Though the action of all excrements has been referred to their inorganic parts only, common experience tends to the explanation which has been given of the joint action of all their parts.

197. The source of nitrogen in dung is an interesting question. Is it ever produced from the hay? That food daily taken, does not contain so much nitrogen as is contained in the evacuated solids. By reference to 189, it appears that a cow consumed 612 lbs. of water, 87 lbs. of potatoes, 167 lbs. of hay. Deducting now, the water drank, the water in the hay which is about 4 per cent., and the water of the potatoes 75 per cent., 182 lbs. of solid food were consumed in seven days, or 26 lbs. per day. The daily evacuation of solids, deducting the water, was 14 pounds.

The evacuated dung contained	3·03	nitrogen.
The hay originally contained	1·67	"
	1·36	

Hence, nearly double the amount of nitrogen contained in the hay eaten, has been voided. Its source must be looked for in the potatoes, and in the atmospheric air, absorbed by the water which was drank. But it is evident from these facts, that dung owes not its value to the nitrogen only, of hay; nor will the effects be different, if the salts only of equivalent portions of dung and hay be taken.

198. If a cow assimilated all the nitrogen of her hay, 25 lbs. of hay would increase her weight daily, by about 8 lbs.; but no one expects such a result, and the balance of the nitrogen goes off in milk, or in liquid excretions. Hence, a milch cow fats not. So long as a greater part of the nitrogen is voided by milk or otherwise, a cow fats not. If she is not parting with nitrogen in milk, a greater portion goes off in dung. Hence, a common observation, that the manure of fattening cattle is richer than that of milch cows, or of cattle not fattening.

199. The difference in the quantity of bile, slime, &c., in a cow fed on hay or on meal, is not very great. A cow was fed six days on meal and water. She consumed in this period,

Indian meal,	96 lbs.,	or per day,	16 lbs.
Hay,	30 "	"	5 "
Water,	330 "	"	55 "
			76 lbs.

There were voided during this period, 330 lbs. of dung, or 55 lbs. daily. She scoured and lost flesh. The evacuation had all the appearance of night soil, and soon evolved a great quantity of ammonia, and though covered in an earthen pot, was soon studded with a crop of exquisitely beautiful fungi. Compared with hay dung, its composition was,

Geine,	17·43,	14·45	in common dung,
Salts,	·93,	·95	" "
Water,	81·64,	83·60	" "

Probably the nitrogen was 2 1-2 per cent., or five times that of common cow-dung.

200. Doubtless the value of all excrements will depend somewhat upon the food of the animal, and the manner of feeding. It may be stated as a general fact, that the manure of cattle, summer-soiled,

is nearly twice the strength of that from the stalls in winter; and all fattening cattle, whether in winter or summer, produce, as has been stated, a still richer vegetable food. Animals fattening on oil cake, gave manure, 12 loads of which exceeded in value of crops raised, 24 of common stock. These remarks show, that some allowance is to be made for the food. The standard refers only to hay and potatoes. But the value due to different food, may not be so great as is commonly supposed. The actual amount of nitrogen, even where vegetable and animal food is concerned, is not materially different. There were two dogs, which were fed, the one on vegetable food alone, the other on animal; at the appointed time, these animals were sacrificed on the altar of physiological experiment, and the chyle examined. The following were the results:

	Vegetable Food.	*Animal Food.*
Water,	93·06	89·02
Fibrine,	·06	·08
Albumen,	4·6	4·7
Salts,	·8	·7

These are the sources of ammonia, if the chyle had been allowed to putrefy.

201. The ammonia in dung, as has been explained, is the source both of the rapid conversion of the hay into soluble geine, and of nitrates. The action of unfermented dung needs no explanation after this exposition. The geine, the salts, carbonic acid, and ammonia, must be formed among the silicates and roots of plants on which they are to act.

202. Having determined the mode of expressing the value of manures, and fixing the standard of value, other manures containing salts and geine,

may now be compared with that, and their value determined, by detailing their constituents.

203. Horse-dung contains:

Water,	71·20
Hay, bile and slime,	27·
Silica,	·64
Phosphate of lime,	·08
Carbonate of lime,	·30
Phosphate of magnesia and soda,	·58
Loss,	·20
	100·00

The food of the horse will of course affect these results, and hence there is found a great discrepancy in the amount of the elements, at different times.

204. Expressing the value compared with cow-dung, we have—

Geine,	27·
Salts,	·96
Water,	71·20

The geine then, is nearly double that in cow-dung, and the salts, which are mostly phosphates of lime, magnesia, and soda, are about the same. If the nitrogen is regarded, it is found about 50 per cent. greater, than in cow-dung. Hence during the chemical actions of the production of ammonia and nitrates, if the heat is in proportion to that action, we may possibly assign a reason, why horse-dung is a hotter manure than cow-dung. The nitrogen in horse-dung is about 3-4 of one per cent. or, this manure contains, in 100 parts:

Geine,	27·
Salts,	·96
Carbonate of ammonia,	3·24

205. Hog manure and night soil. These may be both arranged under one head. Taking night soil in its purest state, its composition may be thus stated:

Water,	75·3
Geine,	23·5
Salts,	1·2

These salts are nearly three-fourths of the whole composed of carbonate, muriate and sulphate of soda. The remainder being composed of phosphates of lime and magnesia; the last is particularly abundant in night soil. Its average quantity of nitrogen, is about 3 1-4 per cent. Night soil, including that of the hog, contains, per 100 parts:

Geine,	23·
Salts,	1·2
Carbonate of ammonia,	15·32

No analysis has yet been made of hog manure, but in its characters it approaches night soil sufficiently, to be ranked with it, for the present purpose. It is the manure of fattening swine only which is to be classed with night soil. The estray and running animals produce only a "cold" manure of little value. The manure of the penned animal, is always combined with his liquid evacuation. This, whose value is stated, (247) gives hog manure a value which places it with night soil. Sheep-dung probably is in this class. Sheep may be said to digest better than cattle. They cut their food finer, and chew it better; they void thus less vegetable fibre. Their excrement is more converted into geine. Fed on hay alone, their excrement is composed of:

Water	67·9
Bilious and extracted matter,	1·7
Humus with slime,	12·8
Hay and vegetable matter,	8·0
Silica,	6·0
Carbonate and phosphate of lime,	2·0
Carbonate, sulphate, and muriate of soda,	1·6
	100·0

Sprengel.

The nitrogen is abundant, and the amount of matter containing this, nearly three-fifths greater than that of cattle dung. The whole is finer divided, and hence speedily putrefies, and evolves ammonia. It is thus one of the hottest of all manures. But, containing as it does, little water, and being in fine compact balls, air cannot act upon it as it would upon cow-dung. Hence, unless moisture is present, sheep-dung undergoes little change. Great care is required in its use. Its ammonia is abundant, hence if uncombined with geine, it burns up the crops. Hence, when there is little geine, little sheep-dung must be used. Where the soil is wet, and that too with little vegetable matter in it, there decomposition rapidly occurs, and the virtue of the dung, its ammonia is lost.

It is said that 1000 sheep folded on an acre of ground one day, would manure it sufficiently to feed 1001 sheep, if their manure could all be saved. So that by this process, land which can, the first year, feed only 1000 sheep, may the next year, by their own droppings, feed 1365. So said Anderson, forty years ago, (Rural Essays.) Sprengel allows that the manure of 1400 sheep for one day, is equal to manuring highly, one acre of land.

206. Thus the three most common substances,

used for manure, cow, horse and hog-dung, including night soil, are reduced to geine, salts and carbonate of ammonia, or nitrogen, its equivalent. It need not be said, that the experience of ages, has proved that these three varieties of manure, possess very different fertilizing properties. These depend not on the salts alone, whose amount and quality is nearly the same in all. Nor on the geine, for that is nearly the same in human and horse excrement. Their fertilizing power then, depends not, as has been asserted, on the salts which would render their agricultural value equal. All experience would prove such an assertion unfounded. But it is said that their relative value depends on their power of producing ammonia.

207. This is a practical view of a practical subject. The nitrogen present in the manure expresses its true value. This position is substantiated by the experience of practical men. The experiments undertaken by order of the Saxon and Prussian authorities, to ascertain whether the contents of the sewers of the cities of Dresden and Berlin, could be applied to fertilizing the barren lands in their vicinity, may be offered to prove its correctness. These varied in every form, and continued for a long period, prove that if a soil without manure, yields a crop of three for one sown, then the same land dressed with cow-dung yields

	7 for one sown,—with		
Horse-dung,	10	"	"
Human manure,	14	"	"

Now the nitrogen in these has been shown, taking the minimum of nitrogen in the human, at 1 1-2 per cent. is as 1 : 1·50 : 3, whilst the above numbers are to each other, as 1 : 1·43 : 2.

Considering how varied is the composition of

night soil, and how much diluted by various mixtures, this agreement is as near as ought to have been expected, in experiments whose objects were so totally different from that of ascertaining the quantity of nitrogen in each different manure.

208. Each substance used for a manure, cannot be considered in detail. Their general composition only, will be mentioned. Among the mixed manures, poudrette, and guano, rank next to night soil. Poudrette, is night soil partly dried in pans and mixed up with variable quantities of ground peat and plaster. Its value will depend on the circumstance, whether its ammonia is saved, or lost, in the manufacture. If sulphate or muriate of lime is added before drying, then the volatile carbonate of ammonia, will be changed into sulphate of ammonia, and sal ammoniac. Thus not only the most valuable portion of night soil will be retained, but, the salts of lime will be much increased. The peat not only retains a portion of gaseous ammonia, but its geine by this act is rendered more soluble. All night soil from vaults has began to evolve ammonia, hence the advantage of mixing ground peat or plaster with night soil, before drying.

209. It is evident therefore, that the value of poudrette, depends on the skill, and honesty of the manufacturer. But allowing these to be what they should be, no consumer of poudrette will think himself wronged, if he discovers ground peat in the article; and allowing this, and the plaster, or other salts added, to compose one-half the weight of this manure, the farmer buys in every hundred pounds of poudrette, 200 pounds of the best human excrement, and in form not only portable, but perfectly inoffensive. The value of good poudrette, depend-

ing on its ammonia, is, compared with cow-dung, as 14 to 1.

210. There is yet another form of poudrette, which though much used in France, has not been introduced here. It is almost one-third animal matter, and it is formed without any offensive evolution of gas, by boiling the offal of the slaughter-house, by steam, into a thick soup, and then mixing the whole into a stiff paste, with sifted coal ashes, and drying. If putrefaction should have begun, the addition of ashes, sweetens the whole, and the prepared "animalized coal," as it is termed, or poudrette, is as sweet to the nose, as garden mould. It is transported in barrels from Paris to the interior, and is a capital manure.

211. Guano is the excrement of sea-birds. It is found on our northern rocks and islands, but its great deposite is on the islands of the southern ocean, between 13° and 21° south latitude. It there forms immense beds, from 60 to 80 feet thick. What a length of time must have elapsed, or how incredible the number of birds, to have produced that pile of guano, whose base, washed by the sea, was observed by our countryman, Mr. Blake, to stretch a mile in length, and to tower 800 to 900 feet high! The composition of ancient guano, countenances the idea of its being the excrements of birds; probably they belonged to that ancient flock, whose huge foot-marks have left their impress on the shores of an estuary, which has since become the sandstone of the Connecticut river valley.

212. The latest analysis of guano, is that of Voelckel, and may be here cited.

Urate of ammonia,	9·
Oxalate of ammonia,	10·6
Oxalate of lime,	7·
Phosphate of ammonia,	6·
Phosphates of ammonia and magnesia,	2·6
Sulphate of potash,	5·5
Sulphate of soda,	3·8
Muriate of ammonia,	4·2
Phosphate of lime,	14·3
Clay and sand,	4·7
Undetermined organic substances, of which about 12 per cent. are soluble in water, a trace of salts of iron and water,	32·3
	100·

An analysis of one sample indicates little of the general character of the deposit. Its value depends chiefly on its volatile constituents, which vary from 1 to 3. Two samples from the same parcel, yielded, Professor Johnston:

No. 1

Water, salts of ammonia, and organic matter,	23·5
Sulphate of soda,	1·8
Common salt and phosphate of soda,	30·3
Phosphates of lime and magnesia, and carbonate of lime,	44·4
	100·

No. 2.

Water and volatile matter,	51·5
Ammonia,	7·
Uric acid,	·8
Common salt and sulphate & phosphate of soda,	11·4
Phosphate of lime,	29·3
	100·0

Ammonia is the most valuable ingredient; next, a peculiar acid, called uric acid, which gradually affords ammonia, after these the bone earth of guano, gives it a permanent effect. The volatile matter acts in the earlier stage of vegetation. It is continually escaping. Hence, fresh fallen guano is always best. It is probably like the recent droppings of the present race of fish-eating birds. These consist almost wholly of uric acid. The excrement of the sea eagle gave in the

Solid Evacuations.		*Liquid Evacuations.*	
Ammonia, - - - -	9·20	Uric acid, - - - -	59·
Uric acid, - - -	84·65	Other salts, - - - -	41·
Phosphate of lime,	6·13		
	100·		100·

Compared with these, guano contains 1-5 to 1-7 of its original organic elements. No substance yields more substances for the wants of plants, in all stages of their growth, than guano.

It is an article of commerce. There are three varieties known in trade. The white, the dark grey, the red brown, which is the most common. The white is the most recent, the red brown the most ancient, and decomposed, the grey intermediate. The actual money value of guano, to the farmer, in England, where it is now somewhat used, does not exceed $5 per cwt. At this price, according to the experience of fair dealers, it can be imported at a reasonable profit. Beyond this, practical men, who have used it, say that the farmer cannot afford to employ it. Mr. Blake thinks it may be afforded for 1 1-2 cent per pound, delivered in the United States. It is much used in Peru, where a spoonful is applied to each hill, as soon as

the corn shows itself. The effects are what the most sanguine could expect, from this natural, concentrated poudrette, consisting both of salts and geine. Allowing, as has been asserted, that the land itself in Peru, contains not a particle of organic matter, guano can be no proof that plants require not geine, containing as it does, by analysis, 12 per cent. of soluble organic matter.

213. The dung of all domestic fowls, and of birds in general, contains salts similar to those in guano; and while this subject is under consideration, the fact may be mentioned, that it has experimentally been proved, that the dung of pigeons is 2-7ths stronger than horse manure. And for stoved mulberries, vines, peaches, and other plants, the droppings of the barn yard fowls, 1 part to from 4 to 10 of water have been found to produce excellent results; the trees having, at the end of two years, the most healthy and luxuriant appearance imaginable. The poultry yard is, to a careful farmer, a rich source of vegetable food. How much a single hen can contribute to increase the crops, may be seen from the following account, from Vauquelin.

214. In ten days a hen eat 7474 grains of oats, which contained of

Phosphate of lime, ...	91·8348	grains.
Silica, ...	141·8616	"
During this time two eggs were laid, whose shells weighed	308·814	"
And contained phosphate of lime,	17·5975	"
Carbonate of lime, ...	276·7095	"
Gluten, ...	9·8725	"
The excrements during the same time, gave of ashes, ...	348·521	"
Composed of carbonate of lime,	39·3511	"
Phosphate of lime, ...	184·5348	"

Silica, ... 124·6351 grains.
Thus voiding in eggs and excrements,
Carbonate of lime, ... 315·0606 "
Phosphate of lime, ... 202·1323 "

Now this is 17·2267 grains less than silica; and in round numbers, 110 grains of phosphate, and 316 grains of carbonate of lime more than the food eaten contained. Probably in all such experiments, where confined to food different from usual, and deprived of their customary habits, all animals draw upon, and in such cases, may be said to eat themselves. The daily amount of bone dust, however, which one hen thus produces in her various droppings, is about 18 1-2 grains, and of carbonate of lime, 3·9 or an annual amount in round numbers, of these two salts, of 1 pound and 3 ounces. Estimating the salts only, it is found that the agricultural value of a single hen per annum, equals the salts contained in 20 bushels of wheat. This places in a strong light, the very great effects produced by a spoonful of guano, to a hill of corn. In Belgium, the annual value of the dung of 400 or 500 head of pigeons, much used in manuring flax, is $25 to $30.

215. And here, having adverted to eggs, attention may be called to a sadly overlooked fact. All around is heard the requiem of departed wheat fields. The burden of the chant is, carbonate of lime! carbonate of lime! The wail is, it is gone! gone! The want of this is the grand characteristic of our soil. The sole cause, in the estimation of some, of all our barrenness, and fruitless attempts, as they say, and would have us believe, at raising wheat. An egg-shell shall put such reasoning or dreaming to flight. A common sized hen's egg weighs about 1000 grains, of which the shell is

about 106 grains. Two per cent. of the shell is albumen or animal matter; 1 per cent. phosphate of lime and magnesia, and the balance or 97 per cent. carbonate of lime. At an egg a day, this is equal to 1 1-2 ounces of dry chalk per week. Whence comes this? From soil, from brick-dust, from grain, meal, &c. But it exists not in soil as carbonate of lime. Animals, like plants, decompose the silicate of lime of soil, and recombining the base, form carbonates, to form egg-shells. Considering the countless thousands of eggs, which are produced by the birds of every feather in New-England, how big a bit of chalk would their shells produce! So of fresh water clams; their shells common throughout New-England, are carbonate of lime. These facts speak volumes. Whenever birds cease to lay eggs, or clams to form shells, then, and not till then, may it be said that New-England soil is barren, because it contains no lime.

216. Flesh, fish, fowl, all animal solids, muscle, gristle, skin, sinews, &c., all afford geine by putrefaction, and evolve vast volumes of ammonia. Salts are more or less present in all animal substances. There are uniformly found in the soft or fluid portions some of the following salts:

Mineral Salts.
- Sulphate and phosphate of lime.
- Phosphates of soda, magnesia & ammonia.
- Sulphate and muriate of potash and soda.
- Carbonates of potash, soda, lime and magnesia.

Vegetable Salts.
- Benzoate, Acetate, Oxalate, Of potash, soda, lime.

Animal Salts.
- Urate of ammonia.
- Lactate of ammonia.

Oxides of iron, manganese, and silica.

In a word, are found in animals, the inorganic parts of soils, the elements of silicates, united with the inorganic acids which existed in the soil, added to the organic, produced by the animal itself. These salts are common to animals and plants, but except in bones, they form only a small part of the living body.

217. In plants there are certain principles, as albumen and gluten, so like animal products, that they have received the name of vegeto-animal. But very late discoveries have proved that they are identical with the fibrine and albumen of animals. That these animal and vegetable products, are modifications of a principle called proteine, has been alluded to, page 84. The late analyses of these various products shed a clear light over the multiform substances, from the animal kingdom, used for manure. They show, how like products arise from the decomposition of plants, and thus assimilate animal and vegetables in the process of forming composts.

Fibrine, or the basis of flesh, or muscular fibre, albumen, and caseine, or the curd of milk and basis of cheese are composed as follows, by Mulder's analysis :—

	Fibrine.	*Albumen.*		*Caseine.*
		Of eggs.	*Of serum.*	
Carbon,	54·56	54·48	54·84	54·96
Nitrogen,	15·72	15·70	15·83	15·80
Hydrogen,	6·90	7·01	7·09	7·15
Oxygen, Phosphorus, Sulphur,	22·83	22·81	22·24	23·09
	100·	100·	100·	100·

The corresponding products of vegetables are, 1st, gluten, and 2d, its peculiar principle detected by Liebig, called vegetable fibrine; 3d, vegetable albumen; 4th, legumine, or vegetable caseine. The two last are identical in composition and properties, with the albumen and caseine of animals. Indeed it has been suggested, that animals, never create either of the above, but draw them ready formed from plants. The composition of the vegetable principles, authorises such a conclusion. By the analyses of Drs. Scherer and Jones in the laboratory of Liebig, these are constituted as follows:

	Gluten.	*Vegetable fibrine.*	*Albumen.*	*Caseine.*
		Average of 3 trials.	of rye, wheat and plants.	
Carbon,	55·22	54·345	54·86	54·138
Nitrogen,	15·98	15·733	15·88	15·672
Hydrogen.	7·42	7·272	7·31	7·156
Oxygen, Sulphur, Phosphorus,	21·38	22·647	21·95	23·034
	100·	100·	100·	100.

Caseine contains no phosphorus, but both animal and vegetable principles, comprised under the above names, are always combined with alkalies, lime, magnesia, iron, sulphur, and phosphoric acid. The above are the organized principles of living bodies, and are distinguished from all others by their nitrogen. Substances not containing this element are said to be organic, but not organized.

218. The above substances, which form the great bulk of animals and no small part of plants, deducting their inorganic elements, compose proteine, whose constituents are:

Carbon,	55·742
Hydrogen,	6·827
Nitrogen,	16·143
Oxygen,	21·288
	100·

This compound is the basis of the animal solids, and soft parts: fibrine or flesh, and albumen, are only compounds of this with sulphur. All the parts of the animal frame are modifications only of proteine.

The peculiar princple of glue, or size, or jelly, called gelatine, never exists in the healthy animal body. It is the product of catalysis. Boiling water is the catalytic agent, and produces it from tendon, ligament, cartilage, skin and bone. The composition of these, will show at once their relation to proteine.

	Tendon.	*Cartilage, or gristle from ribs.*
Carbon,	50·874	50·895
Hydrogen,	7·152	6·962
Nitrogen,	18·320	14·908
Oxygen,	23·754	23·235

(Scherer.)

Horny matter is equally allied to proteine. Its several variations have been divided into two classes: 1st, soft, and 2d, compact. The first includes skin, or the outer part, called cuticle; and the delicate lining membrane of the internal passages, and sacs; and these substances are like constituted. The cuticle of the sole of the foot is composed of:

Carbon,	50·894
Hydrogen,	6·781
Nitrogen,	17·225
Oxygen, Sulphur,	25·099
	100·

(Scherer.)

Compact horny matter includes hair, horn, nails, claws, hoofs, scales. Like all the other compounds of proteine, these contain sulphur, lime, magnesia, &c., and from 1-2 to 2 per cent. of bone earth. The effect of these as phosphates, has been adverted to, section 169. These all give varied portions of ashes. The beard gives about 0·72 per cent.; blond colored hair, 0·3, and the black hair of a Mexican, 0·2; nails, 0·5; wool, 2, and bone, 0·7 per cent. of ashes. These all evolve ammonia by caustic alkali, an effect, which might have been predicted from their composition, which is, according to Scherer:

	Hair.	*Horn.*	*Nails.*	*Wood.*
Carbon,	50·652	51·540	51·089	50·653
Hydrogen,	6·769	6·799	6·824	7·029
Nitrogen,	17·936	17·284	16·901	17·710
Oxygen, Sulphur,	24·643	24·397	25·186	24·608

Hair affords a substance, in addition to its proteine, and to which feathers are analogous. The composition of the last is,

Carbon, ...	52·427
Hydrogen, ...	7·213
Nitrogen, ...	17·893
Oxygen, ...	22·467

Bone itself is allied to proteine by its cartilage which composes nearly one-third the weight, and which boiling water, under pressure, completely extracts in the form of gelatine, or glue.

219. All these varied forms of proteine may be tabulated so as to express at a glance, their relation to each other, if the elements, Carbon, Hydrogen, Nitrogen, and Oxygen, are expressed by C. H. N. O., and to each are added figures, which represent

the number of atoms, entering into the compound. This is called chemical notation, and each set a chemical formula. (55.)

Proteine, ...	C^{48}	H^{36}	N^{6}	O^{14}
Gelatine of tendons, ...	C^{48}	H^{41}	N^{15}	O^{18}
Chondrine, or gelatine of cartilage,	C^{48}	H^{40}	N^{6}	O^{20}
Compact horny matter, ...	C^{48}	H^{39}	N^{7}	O^{17}
Feathers, ...	C^{48}	H^{39}	N^{7}	O^{16}

ilarity of constitution, is, that it enables the chemist to present at one view, animal and vegeta-

But the great practical lesson, taught by this simble substances, as carbon, water ammonia, and carburetted hydrogen. This is the view which the farmer takes, for he knows that these are the elements of manure. Proteine may be resolved into:

		Hydrogen.		
Carbon,	4·242	+0·707	= 4·949	Carb. hydrogen.
	51·500		51·500	Carbon.
Oxygen,	21·388	+2·661	=23·949	Water.
Nitrogen,	16·143	+3·459	=19·602	Ammonia.
	93·173	+6·827	=100·	Proteine.

This is the agricultural view, and expresses at once that this vast variety of substances is compared to cow dung as 32 to 1, when used dry, as manure.

220. For the purposes in view, all animal and vegetable products, may be divided into two classes; that which does, and that which does not, contain nitrogen. The action of these is very distinct, on the elements of soil, and as manures. The first class putrefies, the second does not. The first class forms alkali, the second forms acids. The action of the first depends on nitrogen, that of the second on carbon.

221. The first class contains flesh in all its varieties; blood, skin, sinew, gristle, cartilage, tendons, hair, feathers, wool, hoofs, horns, nails, scales, and one-third, nearly, of bones and teeth. The second class contains fats and oils in all their variety.

222. It is easily understood, then, how woollen rags and flocks become powerful manure. They afford ammonia, and 100 lbs. containing 17 of nitrogen, should be nearly 34 times stronger than 100 lbs. of fresh cow dung. Connected with flocks and wool, there is a very valuable product, rich in all the elements of manure, which is often lost or not used for agricultural purposes, namely, the sweat, or natural soap of wool. Fresh clipped wool loses from 35 to 45 per cent. of its weight by washing. This is due to a peculiar matter exuded from the wool, and which consists chiefly of potash, lime, and magnesia, united to a peculiar animal oil, forming an imperfect soap. It is remarkable that this soap of lime, in all other cases insoluble, is here soluble in water. The experience of the best French agriculturalists, is full of testimony to the good effects of this wool sweat. It has been calculated that the washings from wool, annually consumed in France, are equal to manuring 370,000 acres of land.

223. Bones consist of variable proportions of cartilage, bone earth, and carbonate of lime. The bone earth may be estimated at one-half the weight. It is a peculiar phosphate of lime, containing 8 parts of lime to 3 of phosphoric acid. A great part of the value of bone as manure, depends on its cartilage. The animal part of bones being one-third of their weight, the ammonia is equal to 8 or 10 times that of cow dung, while, if we regard the salts only, 100 lbs. of bone dust, contain nearly 66 times as

much as an equal weight of cow dung. Such statements while they express the chemical facts, are almost, if not quite, supported by the testimony of those who have, in practical agriculture, applied these concentrated animal manures. It is a common opinion, that bones from the soap-boiler have lost a large portion of their animal matter. It is erroneous. Boiling, except under high pressure, extracts very little of the gelatine, and not all the fat and marrow. Heads and shoulder-blades and the smaller bones still contain, after boiling, 3 1-2 per cent. of fat and tallow. If the phosphate of lime of such bones is dissolved out by acid, the animal portion remains, with all the form and bulk of the bone. Bones which are offered in the market, are quite as rich in the elements above stated, as are unboiled bones. The phosphate of lime is rendered quite soluable by its combination with gelatine and albumen. The class of mixed manures, containing nitrogen, has thus been considered. The principle of their action and the foundation of their value, pointed out. The action of the second class, or those not containing nitrogen, remains to be explained.

224. All fats and oils exposed to air give off a great quantity of carbonic acid, and end by becoming acids. As their ultimate elements are the same as those of plants, it may be inferred, that under the influence of growing plants, fats and oils are decomposed and become vegetable food. But there is another action of fats and oils on silicates; they not only let loose the alkali of silicates by the carbonic acid, which they evolve, but the oils now become acids, immediately combine with this alkali, and imperfect soaps are formed. Soaps are truly chemical salts, and hence we have at once a clew to the action of oil and fat.

225. Among the most powerful of manures in the class composed of geine and salts, is soot. There is no one substance so rich in both. Its composition allies it to animal solids, and is as follows:

Geine, ...	30·70
Nitrogen, ...	20·
Salts of lime, mostly chalk, ...	25·31
Bone dust, ...	1·50
Salts of potash and soda, and ammonia,	6·14
Carbon, ...	3·85
Water, ...	12·50
	100·

On the principles adopted for determining the value of manure, the salts in 100 lbs. of soot, are equal to 1 ton of cow dung. Its nitrogen gives it a value, compared with cow dung, as 40 to 1.

226. Soot forms a capital liquid manure, for the floriculturist. Mixed with water, in the proportion of 6 quarts of soot to 1 hogshead, it has been found to be a most efficacious liquid, with which to water green-house plants; and being not only a come-at-able, but a comely preparation, it may recommend itself to the cultivator of flowers, by these lady-like qualities.

The most decided good results have been produced in England on Stinchcombe farm, containing 200 acres of arable land, by soot, barn yard manure, and sheep dung. The rotation is turnips, potatoes, wheat. The average produce of the potatoes, 315 bushels; of the wheat, 28 bushels per acre. The turnips are manured by that produced by 12 oxen and 5 horses, 4 of which are employed in carting the crops to market and hauling

back soot, often a distance of 25 miles. The turnips are fed off by sheep, and each acre, in turnips receives at the rate of the manure of 2000 sheep for one day (205). The potatoes and wheat are each manured with soot only, at the rate of between 11 and 12 bushels per acre. The annual quantity used, being about 3000 bushels, at the cost of about a 6d English, say 12 1-2 cts per bushel. By this treatment for 30 years the quantity of crops and the quality of the land have improved year by year. Anthracite coal soot, as it may be called, contains no geine. It contains abundant salts of ammonia. Mixed with swamp muck and alkali at the rate of two bushels per cord, there can be no doubt that the good effects of soft coal, or wood soot would be produced. The fine dust which collects about the flues of boilers when anthracite is used, thus becomes of great agricultural value. From an accurate experiment on 106·504 pounds of coal, I find the quantity of this ash, collecting about flues is 5·09 per cent. of the coal consumed.

227. Among the mixed manures, is the salt, or spent ley of the soap-boiler. It seems to offer a natural passage, from this class to those consisting of salts only. To understand its components, the chemical composition of oil and fat must be briefly studied. No products of life are now better understood, than the fatty bodies. They are all acids, combined with a peculiar organic base, which acts the part of an oxide. This is never obtained except in combination with oxygen and water. In this state it has long been known under the name of glycerine. The acids combined with it, are stearic, magaric and oleic. By the union of these acids with glycerine, stearine and margarine, or fats, and oleine or oil is produced. In soap making, the alkali

used, decomposes stearine, and oleine, combining with their acids, which thus are converted into stearates, margarates, and oleates of alkali, or soap, while the glycerine remains free in the spent ley with the salts, which that contains.

228. The proportion of glycerine, in fat and oil, is about 8 per cent. Its composition is—

Carbon,	40·07	These are in such proportion as to form water, free carbon and carburetted hydrogen.	or	Carbon,	24·77
Oxygen,	51·00			Car. hyd.	17·85
Hydrogen,	8·92			Water,	57·37

Glycerine is transparent and liquid, and was called the sweet principle of oils, from its sweet taste.

229. The glycerine is thus the organic, or geine part of salt ley. Its proportion in that will vary, if the spent ley is boiled, as is usual, upon a fresh portion of tallow, which adds its quantity of glycerine, in proportion to the alkali in the ley.

230. The salts are various, and depend on the kind of alkali used to form the ley. The alkali is derived from barilla, from soda or white ash, from potash, or from ashes. Hence no general statement can be given, which shall express the value of spent ley salts. That some idea may be formed, of its components, it may be divided into two kinds: 1st, that produced from soft soap, or from ashes, or potash; 2dly, that from hard soap, barilla, or soda ash. A boil of 2000 lbs. of soft soap, requires 150 bushels of ashes, and its spent ley contains, in addition to a little free potash, the following salts, derived from ashes:

130 lbs. of Sulphate of potash,
6 " of Muriate of potash,
36 " of Silicate of potash,

allowing the ashes to have been a mixture of oak, bass, and birch woods. Besides these, in the process of soap making, in order to make the soap "grain," common salt is added. A chemical change is thus induced, the potash soap, is changed to soda soap, or the soft to hard. The soda of the salt entering the soap is replaced by the potash, which combines with the acid of the salt, that is chlorine or muriatic acid. In other words, common salt, or chloride of sodium, or muriate of soda is changed to chloride of potassium, or muriate of potash, which is thus added to the spent ley. The proportion of salt added, varies, but it may be stated in general, 7 bushels, or 500 lbs. to 150 bushels of ashes. In a boil, then, of 2000 lbs. of soap, 1200 lbs. of fat or tallow, containing 100 lbs. of glycerine,

150 bushels of ashes,
7 bushels or salt,

afford about 200 gallons of spent ley. This contains the glycerine and salts above, (230) and affords per gallon,

	Geine or glycerine,	1-2 lb.
Salts,	Muriate of potash,	5 1-3 lbs.
	Sulphate of potash,	1 1-3 lbs.
	Silicate of potash,	2 1-2 oz.

231. The spent ley from soda soap, contains the sulphate and muriate of soda of the soda ash, which rarely amounts to 12 per cent. As less salt is here added, the spent ley is less rich in salts. In a boil of 2000 pounds of hard soap, 600 weight of white ash are used. Including the one bushel of salt usually added, the spent ley contains,

Sulphate of soda,	84 lbs.	or per gallon,	6 3-4 oz.
Muriate of soda,	106 "	"	1-2 lb.
Glycerine,	100 "	"	1-2 lb.

232. The value of spent ley has been tested for a series of years. It has shown its good effects on grass lands, for four or five years after its application. There is great advantage in carrying it out upon snow. It has then the effect of converting any carbonate of ammonia in the snow, into sal ammoniac, or a volatile into a fixed salt.

233. When it is thus understood, on what the value of spent ley depends, it would seem probable, that the farmer may himself prepare it, and unless he resides in the neighborhood of a soap-boiler, at a cheaper rate than he can buy and cart home this liquid manure. A hogshead of spent ley, of 100 gallons, contains, if from ashes,

50	pounds of	glycerine or geine,
53	"	muriate of potash,
13	"	sulphate of potash.

The salts may easily be supplied. It becomes a highly interesting question, whether the glycerine has any specific action, any action which the light of chemistry may not kindle in similar substances. By reference to (228) its chemical constitution, approaches geine, and they are here presented side by side.

	Glycerine.	*Geine of Soil.*
Carbon,	40·07,	58·00
Hydrogen,	8·92,	2·18
Oxygen,	51·00,	39·90

234. The glycerine resolves itself into water, free carbon and carburetted hydrogen, or the gas of marshes or stagnant pools; the geine into car-

bon and water. In the series of changes which they may undergo, let it be supposed, that carburetted hydrogen gas, is evolved by glycerine. There is no reason for assuming, as do some, that carbonic acid, is the only source of the carbon of plants. The volumes of carburetted hydrogen produced in the decay of plants, may be intended as well as carbonic acid for their nutriment. Suppose, of which there is no doubt, that carburetted hydrogen of glycerine, contributes to this effect, there remains then free carbon, which being perfectly insoluble and changeless, acts only by condensing gases in its pores.

235. Geine, by tillage, air and moisture, evolves also, carbonic acid. As gas, no one will deny that it thus affords carbon to plants; its carbonic acid is absorbed and its carbon assimilated, and hence, if either glycerine or geine afford carbon, the circumstances under which they may be applied to the land, are less favorable to the production of carburetted hydrogen, than of carbonic acid. The balance then is in favor of geine.

236. There are two circumstances wherein geine and glycerine differ. The latter is soluble to any extent in water, it is applied to the land in spent ley, already dissolved. The action so evident, is due to one of two causes, or to their joint action. Spent ley, acts either by its organic, or by its inorganic part, by its glycerine, or by its salts. Those who take the ground, that humus or geine, never is taken up by plants, will then attribute all the decided good effects of spent ley to its salts. Glauber's and common salts applied in equal quantity, to that contained in soda spent ley should produce equally good effects. It is well known that such is not the fact. Nor will those who maintain this doctrine,

admit that glycerine acts by its evolving gases, for then, an equal weight of peat would answer. It is well known that such is not the fact.

237. If spent ley then acts neither by its salts, nor its evolved gas, it acts by the perfectly dissolved state of its glycerine. That such is the case, admits not of a doubt, and goes to show that plants appropriate the geine or humus of soil, by absorbing it as geine or geates.

238. The spent ley acts, both by its salts and its geine. The action of salts has been explained. The soluble state of geine is the most important fact to be borne in mind, if it is attempted to make spent ley on a farm. Swamp muck, or peat, ashes, and common salt, will afford all the elements of spent ley, and the following may be proposed, as an imitation of that from soda soap.

Fine dry snuffy peat, ...	50 lbs.
Salt, ...	1-2 bushel.
Ashes, ...	1 "
Water, ...	100 gallons

Mix the ashes and peat well together, sprinkling with water to moisten a little, let the heap lie for a week. Dissolve the salt in the water, in a hogshead, and add to the brine, the mixture of peat and ashes, stirring well the while. Let it be stirred occasionally for a week, and it will be fit for use. Apply it as spent ley, grounds and all. Both ashes and salts may be doubled and trebled, with advantage, if convenient. The mixture of ley must be used before it begins to putrefy; this occurs in three or four weeks. It then evolves sulphuretted hydrogen gas, or the smell of gas of rotten eggs; this arises from the decomposition of the sulphates in the water and ashes, by the vegetable

matter. A portion of the geine is thus deposited from the solution.

239. Having thus considered the class of mixed manures, or those composed of geine and salts, those consisting of salts only, are to be now explained. They are next in value to the mixed manures. They are chiefly the liquid evacuations of animals, and when artificially combined with geine, their value exceeds that of the solid evacuations. These liquids equal, in fact, the mixed manures of the most fertilizing energy. The liquid evacuations are truly salts only, dissolved in water; but they are salts of a peculiar character in many cases, and are formed of an animal acid. This is it which renders a detailed account of these manures interesting to the farmer. It is not enough for this purpose to refer the action of these liquids to the general effect of salts on mineral manures.

240. The peculiar animal acid to which reference has been made, becomes like nitric acid in nitrates, the food of plants. The element from which it is derived gives a marked and highly valuable character to the liquid evacuations of the farm yard, and household. This peculiar animal principle is urea. It may be obtained from these liquids, in transparent, but colorless crystals of a faint but peculiar odor. Cold water dissolves more than its weight, and boiling water an indefinite quantity of crystals of urea. The pure crystals undergo no change, when dissolved in pure water, but if they are mixed with the other ingredients of the urine, decomposition rapidly ensues, and they are resolved almost entirely into carbonate of ammonia. Alkalies and alkaline earths induce similar changes on urea. The practical value of this fact will be easily understood.

241. Pure urea has no distinct alkaline properties. It unites with aqua fortis, or nitric acid, and forms a sparingly soluble salt, composed of about equal parts of each of its ingredients.

242. Urea is composed, according to Dr. Prout, of carbon 19·99, oxygen 26·66, hydrogen 6·66, nitrogen 46·66. These elements are so beautifully balanced, that they afford only carbonic acid and ammonia; though the chemistry of every reader, may not understand how these elements produce cyanic acid and ammonia. The salt cyanate of ammonia, has actually been formed by modern chemistry, which has thus succeeded in forming a true organic product, or product of living action, or rather of chemical action guided by living principle. In all animal evacuations containing urea, that may be considered, as so much carbonate of ammonia of the shops.

243. The peculiar animal acid which has been mentioned as forming so essential a part in these liquid excretions, is called uric acid. It is not, like urea, changed by exposure, into ammonia. It contains a large portion of nitrogen, which, under the influence of growing plants, is let loose, and may then form ammonia. Its composition is as follows: carbon 36·11, hydrogen 2·34, oxygen 28·19, nitrogen 33·36.

The peculiar principles of the liquid evacuations having been explained, their constitution may be now stated. They are, it will be remembered, at the head of the class of manures composed of salts. First, the liquid evacution of cattle, what is its agricultural value as a manure? Its composition will form the answer.

Cow's urine was long ago examined by Brandt, whose results, have formed the basis of all calcula-

tions of its value for almost half a century. It is evidently defective. The more exact analysis of cattle urine, by Sprengel, who has devoted particular care to the subject, gives, as the average of many trials, the following, in 1000 lbs.

Water,		926·24
Urea,		40·00
Albumen,		·10
Mucus or slime,		1·90
Hippuric acid,	combined with potash, soda and ammonia, forming salts,	·90
Lactic acid,		5·16
Carbonic acid,		2·56
Ammonia,		2·05
Potash,		6·64
Soda,		5·54
Sulphuric acid,	combined with soda, lime & magnesia, forming salts,	4·05
Phosphoric acid,		·70
Chlorine,		2·72
Lime,		·65
Magnesia,		·36
Alumina,		·02
Oxide of iron,		·04
Oxide of manganese,		·01
Silica,		·36
		1000·00

Let this now be compared with the standard of value, cow dung. 100 lbs. of that afford 2 lbs. of carbonate of ammonia; while this evacuation gives 4 lbs. of ammonia in its urea, besides that in its other ammoniacal salts.

244. The quantity of liquid manure produced by one cow annually, is equal to fertilizing 1 1-4 acres of ground, producing effects as durable as do the solid evacuations. A cord of loam, saturated with urine, is equal to a cord of the best rotted dung.

If the liquid and the solid evacuations including the litter, are kept separate, and soaking up the liquid by loam, it has been found they will manure land, in proportion by bulk of 7 liquid to 6 solid, while their actual value is as 2 to 1.

245. 100 lbs. of cow's urine afford about 8 lbs. of the most powerful salts which have ever been used by farmers. The simple statement then, in figures, of difference in value of the solid and liquid evacuations of a cow, should impress upon all the importance of saving the last in preference to the first. Let both be saved. If the liquids contained naturally, geine, they might be applied alone. It is the want of that guiding principle which teaches that salts and geine should go hand in hand, which has sometimes led to results in the application of the liquor, which have given this substance a bad name.

246. It has been proved that the ammoniacal salts of urine have a forcing power on vegetation. The value of ammonia was long ago understood by Davy, and its carbonate was his favorite application. Plants watered with a simple solution of sulphate of ammonia, an abundant salt in cow's urine, are 15 days earlier than those watered with pure water. Grass land watered with urine only, yields nearly double to that not so manured. In a garden on land of very poor quality, near Glasgow, urine diluted with water, nearly doubled the grass. But upon wheat, sown on clay land, it did no good; it injured barley, potatoes grew rank and watery, and on turnips the effects were only half as good, as mere unfermented dung. The circumstance of the soil in this last case, was probably a deficiency of geine.

247. The liquid evacuation of the horse is composed of

Water,	94·
Urea,	·7
Chalk,	1·1
Carbonate of soda,	·9
Hippurate of soda,	2·4
Muriate of potash,	·9

The hippuric acid is not peculiar to the horse. The urine of most herbiverous animals contains hippurate, formerly called benzoate of soda, its acid having the fragrance of gum benzoin. If man takes benzoic acid, hippuric replaces uric acid in the urine. According to the composition, horse stale, pound for pound, is equal to the value of cow dung. Sprengel found the urine of sheep to afford, in 1000 lbs.,

Water,	980
Urea, with some albumen,	28
Salts of potash, soda, lime, magnesia, with traces of silica, alumina, iron and manganese,	12
	1000

No animal affords more urine than the hog. Owing to a peculiar volatile and unexamined substance, it gives plants and roots a disagreeable taste. Fed on grains and bran, the urine in 1000 lbs. affords,

Water,	926·
Urea, with a little slime and albumen,	56·40
Salts, common salt, muriate of potash, gypsum, chalk, Glauber's salts,	17·60
	1000·

248. But rich as are the liquid evacuations of

the stable and cow yard, they are surpassed by those of the farmer's own dwelling, especially when it is considered with what ease these last may be saved. According to Dr. Thomson, 1000 parts of this substance, the human liquid evacuation, contain 42 1-2 lbs. nearly of salts, which are,

Sal ammoniac, ...	·459
Sulphate of potash, ...	2·112
Muriate of potash, ...	3·674
Common salt, ...	5·060
Phosphate of soda, ...	4·267
Bone dust, (phosphate of lime,) . . .	·209
Acetate of soda, ...	2·770
Urate of ammonia, ...	·298
Urea with coloring matter, ...	23·640
	42·489
Water, ...	957·511

There is scarcely a single element in this liquid which is not essentially an ingredient in all plants.

In every 100 lbs. of cow urine, are,

Urea, ...	4·	lbs.
Of horse urine, ...	·70	"
Of human urine, ...	2·36	"
Of sheep urine, ...	2·80	"
Of hog urine, ...	5.64	"

It is at once seen, how valuable are swine, as manufacturers of manure.

249. The urea being called equal to ammonia, it is seen that the ammoniacal salts in human urine are very nearly the same as those in cow dung, but its effects in actual practice are found to be nearly double those in cow dung. The actual amount of salts in 100 parts of human, cow, and horse dung,

is in round numbers, 1 per cent., while in the liquids it averages 5·88, being in the cow 7·4, and in the human 4·24 per cent., horse 6.

250. All urine of course varies with the food of the animal, the season, and its age. White turnips give a weaker liquor than Swedish. Green grass is still worse. Distillers' grains are said to be better than either of these. The more water the animal drinks, the poorer the urine. Doubtless the liquids of fattening kine are richer in ammonia during this period, for it contains a part of that nitrogen not carried away in milk. In winter, urine contains much less urea than in summer, sometimes only one-half. Putrefaction changes urea to ammonia. The time required for this varies. Urine putrefying for a month, contains double the ammonia of fresh urine. It does not wholly decompose in a month; but during all this time, gives off ammonia. Unless then mixed with loam, or peat, or swamp muck, or where kept in tanks with its bulk of water, it loses ammonia. Urine is fully ripe, when it contains neither caustic ammonia, nor urea. Whatever may be the food, it is evident from the above statements, that rivers of riches run away from farms, from want of attention to saving that which ordinarily is allowed to be wasted.

251. Each man evacuates annually, enough salts, to manure an acre of land. Some form of geine only is to be added to keep the land in heart, if the farmer has but the heart to collect and use that which many allow, like the flower unseen, "to waste its sweetness on the desert air."

252. But with all the farmer's care, with every convenience for collecting and preserving these animal products, still the amount which can be so collected, is often wholly inadequate to the wants of

the farmer of small means. All these accumulations presuppose a goodly stock of animals on the farm. This again is limited by the means of keeping, and so one influences the other. The farmer wants some source of manure, which while it produces the salts and geine of an unlimited amount of stock, hogs and hens, shall yet require no more barn room, fodder or team, than every man who means that his hands and lands shall shelter, feed, and clothe him, can easily command.

CHAPTER VII.

ARTIFICIAL MANURES, AND IRRIGATION.

253. The class of salts as manure, is to be distinguished from the salts, called mineral manures, by this circumstance, that they contain large portions of peculiar animal products, called urea, and uric acid. These afford ammonia, in large quantity, by their decomposition. Having considered the relative value of the two classes of manure, those composed of salts, and of salts and geine, that consisting chiefly of geine, is now to be explained.

254. First and foremost in this class, is swamp muck, mud, or peat. This class includes also, dry leaves, dry vegetables of all sorts; ploughing in of green or dry crops, irrigation. These are fruitful topics. The principles only of their action, can be pointed out. The application of the principle, must be left to the farmer. The why, of things has been shown; the how, must be deduced from the why, by practical men.

255. Peat is too well known, to render it necessary to say, that it is the result of that spontaneous change in vegetable matter, which ends in geine. Peat is, among manures consisting chiefly of geine, what bone dust is, among manures, consisting of

animal matter. Peat is highly concentrated vegetable food. When the state in which this food exists, is examined, it is found not only partly cooked, but seasoned.

256. Peat consists of soluble and insoluble geine and salts. The proportion of these several ingredients must be known, before the value of peat can be compared with similar constituents in cow dung. This proportion is exhibited in the following table of constitution of Massachusetts peat per 100 parts:

	Locality.	*Soluble Geine.*	*Insoluble Geine.*	*Total Geine.*	*Salts and Silicates.*
1.	Dracut,	14·	72·	86·	14.
2.	Sunderland,	26·	56·60	85·60	14·40
3.	Westborough,	48·80	43·60	92·40	7·60
4.	Hadley,	34·	60·	94·	6·
5.	Northampton,	38·30	44·15	82·45	17·55
6.	"	32·	54·90	86·90	13·10
7.	"	12·	60·85	72·85	27·15
8.	"	10·	49·45	59·45	40·55
9.	"	33·	59·	92·	8·
10.	"	46·	46·80	92·80	7·20
	Average,	29 41	55·03	84·44	15 55
11.	Watertown, pond mud,	5·10	8·90	14·	86·
12.	Danvers, pond mud,	8·10	6·50	14·60	84·40

257. Under the general name of peat, are comprised several varieties, which may be distinguished as, 1st. Peat, the compact substance generally known and used for fuel, under this name. 2d. Turf, or swamp muck, by which is to be understood, the paring which is removed before peat is dug. It is a less compact variety of peat. It is common in all meadows and swamps, and includes the hassocks. Both these varieties are included in

the above, from No. 1 to No. 10. It includes also, the mud of salt-marshes. 3d. Pond mud, the slushy material, found at the bottom of ponds when dry, or in low grounds, the wash of higher lands. This seldom contains more than 20 per cent. of geine. Nos. 11 and 12, are of this description.

258. These varieties comprise probably a fair sample of all the peat and swamp muck and pond mud, which occur in the various parts of the country. The results stated, (256) are those of the several varieties, when dried, at a temperature of 240° F. The composition of peat ashes has been alluded to (163). They contain, in fact, all the inorganic principles of plants, which are insoluble, with occasional traces of the soluble alkaline sulphates, and of free alkali.

259. It is well known that all peat shrinks by drying, and when perfectly dried, at 240° F. loses from 73 to 97 per cent. of water. When allowed to drain as dry, as it will, it still contains, about 2-3 of its weight of water. It shrinks from 2-3 to 3-4 of its bulk. A cord wet becomes 1-4 to 1-3 of a cord when dry. To compare its value with cow dung, equal bulks must be taken, and hence, to dry peat, a bulk of water must be supposed to be added, in proportion above stated, or still better, because easier done, the pile of dry peat is to be estimated by the pit left after digging. It will be found on the above data, that 100 parts of fresh dug peat, of average quality, contain—

Water,	85·
Salts of lime,	·50
Silicates,	·50
Geine,	14·
	100·

This does not differ much from fresh cow dung, so far as salts, geine, and water are concerned. The salts of lime, are actually about the same, while the alumina, oxide of iron, magnesia, in the silicates added to the salts of lime, make the total amount of salts in round numbers, equal that of cow dung.

If the bulks of these are compared, it will be found, that at 90 lbs. per bushel, full measure, and 103 bushels being allowed to a cord,—each contains and weighs as follows, in pounds:

	Weight	*Soluble Geine.*	*Insoluble Geine.*	*Total Geine.*	*Salts of Lime.*
Dung,	9289	128	1288	1416	92
No. 9 peat of table,	9216	376	673	1049	91
No. 10 " "	9216	519	529	1048	81

A cord of pond mud, (No. 11,) weighs when dug, 6117 lbs. and contains solid matter, 3495 lbs. composed of geine, 495 lbs.; of silicates and salts, 3005 lbs. The salts of lime in pond mud, are 2 1-2 per cent.

260. The salts and geine of a cord of peat are equal to the manure of one cow for three months. It is certainly a very curious coincidence of results, that nature herself, should have prepared a substance, whose agricultural value approaches so near cow dung, the type of manures. This subject may have been now sufficiently explained. Departing from cow dung and wandering through all the varieties of animal and vegetable manures, we land in a peat-bog. The substance under our feet is analyzed, and found to be cow dung, without its musky breath of cow odor, or the power of generating ammonia. That process is over—a part of the ammonia remains, still evident to the senses by adding caustic potash. It exists in part, either as a

component of crenic and apocrenic acid, or combined with geine, or as phosphate of ammonia, and when the presence of ammonia is added to the salts, whose existence has already been pointed out, it may be said, that peat approaches dung, moistened with the liquid evacuation of the animal.

261. The power of producing alkaline action, on the insoluble geine, is alone wanted to make peat good cow dung. Reviewing the various matters, from whatever source derived, solid or liquid, which are used as manure, all possess one common property, that of generating ammonia. The conclusion then of this whole matter, is this; the value of all manures, depends on salts, geine, and ammonia; and it is directly in proportion to the last; it follows, that any substance affording these elements, may be substituted for manure.

262. The great question comes, how is to be given to peat, a substance which, in all its other characters, is so nearly allied to cow dung, that lacking element ammonia? How is that to be supplied? Without it, cow dung itself would be no better than peat, nay, not so good; for in peat, nearly one-half of the geine, is already in a soluble state. Passing by the fact, already alluded to, that peat contains traces of ammonia, which, evolved when treated with caustic potash, exerts its usual action; it may be added, that possibly in the process of vegetation, when the decomposing power of the living plant is exerted on peat, and the silicates, caustic potash is produced, and ammonia evolved. Considering peat as a source of nitrogen only, it is evident that the action of alkali is of the highest practical importance.

263. In this part of the subject of manure, probabilities and possibilities are no longer admissible.

There are two facts well established by experience, relating to the action of ammonia in dung. First, it has been shown (166) that dung produces nitrates. Porous substances and alkali, possess the power of forming nitrates; these substances, alkali and porous substances, act like spongy platina, they induce a catalytic power, and the consequence is, that the elements of the air, oxygen and nitrogen unite, and form nitric acid, this combines with the alkali, and consequently nitrates are produced. The other well established fact, in relation to the action of ammonia in dung, is the power of dissolving and converting geine, which has been explained in Chap. IV. The most valuable of these two properties is that of producing soluble geine. The formation of nitrates may be quite, and ordinarily is prevented. It is the alkaline action which is sought.

264. By then, the addition of alkali to peat, it is put into the state, which ammonia gives to dung. The question then arises, how much alkali is to be added to swamp muck or peat, to convert that into cow dung? Recurring to the doctrine of chemical proportions, whose value to the farmer is thus made evident, it will be remembered that the equivalent of potash and soda, that is, that portion of one which can take the place of the other, is as 2 to 3; that is, 2 parts of soda are equal to 3 of potash. If either of these is compared with ammonia, it will be found that one part of ammonia is nearly equal to two of soda. When these substances are met with in commerce, it is in the state of salts; as carbonate of ammonia of the shops, or white ash or potash and pearlash. The equivalent of these, is deduced from determining the pure alkali of each, adding the equivalent of carbonic acid, and to this the usual impurity. It is found that

59 parts of ammonia, are equal to
58 " soda, or white ash, or to
72 " 1st quality pot or pearlash, or
86 " 2d quality pot or pearlash.

265. For all agricultural purposes, is may be considered, that salts of hartshorn, or carbonate of ammonia, and white or soda ash, are equal, pound for pound, and that pots and pearls may be taken at one-half more.

266. If all the nitrogen in dung, becomes ammonia, then as has been shown, (187) each 100 lbs. affords 2 lbs. 2 oz. Discarding fractions, let it be called 2 lbs. Hence, if to 100 lbs. fresh dug peat, there are added 2 lbs. soda ash, or 3 lbs. of pot or pearl ashes, all the good effects of real cow dung will be produced. Peat or muck, thus requires 2 per cent. of soda ash, or 3 per cent. of potash.

267. By (259) a cord of green peat weighs 9216 lbs.; 2 per cent. are 184 lbs. Hence a cord requires that amount of soda ash, or 276 lbs. of potash. But if the peat is quite dry, so as to have lost 3-4 of its bulk, then 736 lbs. of soda ash, or 1104 lbs. potash will be necessary. Two per cent. of alkali seems enormous. It is stated, in the hope that it may lead to experiments on the free use of alkali. But as it will be hereafter shown, that this is to be reduced by mixing with loam or other matter, this quantity, even if applied to one acre, will probably produce very good effects. It has repeatedly been proved for other purposes, that a cord of fresh dug peat neutralizes 100 lbs. of soda ash, or 400 lbs. to a dry cord. Further, dry peat, by boiling with, neutralizes, 12 1-2 per cent. of its weight of potash, and in actual practice, alkali to the amount of 6 per cent. of the weight of the geine, in pond

mud, has been used. It would therefore appear to be safe to use the theoretical proportion.

268. But the nitrogen in cow dung, does not all tell. It is impossible but that some portion of the elements of ammonia, enter into other combinations, and part also escapes as gas. Besides, it is not all brought at once into action, and hence, a less portion of alkali than above indicated, may be used. It is probable that not a third of the ammonia acts. Let it be taken at that quantity. Then the equivalents are 100 lbs. fresh peat, and 10 2-3 ounces soda, or 1 lb. of potash, or 1 per cent. of the weight of the peat in commercial potash.

269. This proportion will allow in round numbers, to every cord of fresh dug peat, 92 lbs. pot or pearl ashes, or 61 lbs. of soda, or 16 to 20 bushels of common house ashes.

Having no guide here, from experience, of the quantity, which may be used per acre, yet in order to arrive at conclusions, which could be recommended safely, the alkali has been calculated in the quantity of saltpetre which has been used, with such signal success by O. M. Whipple, Esq., of Lowell, no less distinguished for the good sense with which he undertakes an experiment, than for the public spirit which urges him onward to its successful conclusion. On the principles which have been developed, when saltpetre is used, the whole alkali is let loose by the action of the growing plant. The experience of Mr. Whipple, is a guide to the quantity of alkali which may be safely used. He has used from 50 to 150 lbs. saltpetre per acre. The real alkali in saltpetre, may be called 1-2 of its weight; or the real alkali used, has been from 25 to 75 lbs.=36 1-2 lbs. and 109 1-2 lbs. pure carbonate; or in round numbers, an average of com-

mercial 1st and 2d quality, of 49 to 149 lbs. per acre—giving an average of 99 lbs. which is nearly 1 per cent. of the weight of a cord of green peat, which agrees with the estimate (268). If then, this is mixed with the usual proportion of geine, which the dung used contains, equally good effects per acre ought to be produced.

270. There are other practical facts, which may help to a solution of the question, how much alkali is to be added to a cord of peat. According to the experience of Mr. Phinney of Lexington, an authority which may not be questioned, a cord of green dung converts twice its bulk of peat, into a manure, of equal value to itself—that is a cord of clear stable dung, composted with two of peat, forms a manure of equal value to three cords of green dung. Indeed, the permanent effects of this compost, according to Mr Phinney, exceed those of stable dung. On this fact, 2 lbs. of ammonia in 100 of cow dung, should convert 200 lbs. of fresh dug peat into good cow dung. The equivalents of these, as has been shown, (265), are 2 lbs. of soda ash, or 3 lbs. of potash. Allowing the gaseous ammonia to be divided equally among the 300 lbs. of dung and peat, this is in proportion of 10 2-3 oz. of soda ash, or 1 lb. of potash to 100 lbs. of fresh peat. Now this calculation, deduced from actual experiment, confirms the theoretical proportions (268,) supposing only 1-3 of the nitrogen acts, though that was made before the author met with the statement of Mr. Phinney.

271. There is a coincidence here of proportions, which makes it quite certain, that the quantity recommended, (269) is a perfectly safe basis for agricultural use. By theory, the proportions are, 1 cord peat, 61 lbs. soda ash, 92 lbs. potash. As de-

duced from the compounds of dung and peat, 61 lbs. soda ash, 92 lbs. potash. This proportion gives each cord of peat a value equal to that of cow dung; if 1-3 of its nitrogen acts, it may be composted, as that is, with loam or still better, mixed up at once with its proportion of peat. If this is done, then the result will be, in round numbers. 1 cord of fresh dug peat,—20 lbs. of soda ash, 30 lbs. potash. In March, 1849, the author, in a letter addressed to the commissioner for the agricultural survey of Massachusetts, threw out the following hint, which was published in the second report of of Mr. Colman:

"Take 100 lbs. of peat as sold or the fine part from the bottom of a peat stack—at any rate, bruise the peat fine, put it into a potash kettle, and 2 1-2 lbs. of white ash, and 130 gallons of water; boil for a few hours: let it settle, dip off the clear for use, add 100 lbs. more of peat, 2 1-2 lbs. white ash, fill up with water, as much as you have dipped off, boil again, settle and dip off. This may be repeated five times. How much oftener I know not; probably as long as the vegetable part of peat remains. The clear liquor is an alkaline solution of geine. The three first boilings contain geine, alumine, iron, magnesia, and sulphate or phosphate of alkali. The dark colored solution contains about half an ounce per gallon, of vegetable matter."

"It is to be applied by watering grass lands. The 'dregs' may be mixed up with the manure or spread as a top dressing; or put in the hill. Experience will teach—I only suggest."

The principle which should guide the farmer in the making of artificial manure, has now been considered. The author of these pages is not a practical farmer, agriculture is not his pursuit, and he

has studied his chemistry, only as a recreation from the daily duties of life. He has thrown out suggestions, the result of researches, undertaken with reference to a totally different object, and these suggestions have been acted upon by practical men, whose results confirm his previous anticipations. He has no theory on this subject to maintain, his opinions must stand or fall by practice, speak for themselves. Yet he is not altogether indifferent to the practical results which may follow his suggestions, and he should consider that he had inflicted a serious injury on agriculture by the publication of erroneous opinions. When a man's character is to be established in a court of evidence, what is the rule? The good old English rule? To call upon the bystanders, the country present, taken indiscriminately from all who may have known the person. Do not summon persons whose interest may throw a shadow of suspicion, on the testimony of the witness. And so here, let it be proved if it can be, whether the principles here advanced, are of practical value, by calling upon the stand, those gentlemen who have tested his opinions, and of some of whose operations and results he was ignorant, till he met with them in the agricultural publications of the day, or in accidental conversation; others have been requested to state by letter their results, after these pages were prepared for the press. The evidence on this point is contained in the appendix to this volume.

272. Attention might here be called, to the extended use of peat, composted with lime and animal manure; but it will be observed, that it is wished to direct the thoughts at this time, to a compost or artificial manure, without lime or animal manure. The author does not go for lime, but for

soluble alkali. Carbonate of lime alone, is not expected to produce immediate results, and seldom has, nor can be expected to produce visible effects in the first year of its application. The why and the wherefore of this has been already explained, and it is merely adverted to now to guard against any inference favorable to the action of lime, being deduced from the following facts. Mr. George Robbins, of Watertown, is an extensive manufacturer of soap and candles and of starch, and still better, a man who employs the refuse of these trades, in enriching and gladdening his land. For four years, and it is believed his crops will compare with any of the best cultivators around him, he has not used a spoonful of manure made by any animal, walking either on two legs or on four. He keeps a large number of horses and hogs, and several cows; he uses not a shovelful of their manure, but selling that, he uses peat and swamp muck, mixed with his spent barilla ashes. The proportions are, one part of spent ashes to three of peat, dug up in the fall, mixed in the spring. After shovelling two or three times, it is spread and ploughed in. The effect is immediate, and so far, lasting. The effects of this spent ashes alone on sandy loam, are excellent; it makes the whole quite "salvy."

273. The composition of spent ashes has already been alluded to; a certain portion is carbonate of lime; it is well known, that as such, it would produce no better effects than so much chalk. A large part of silicate of soda exists in the spent ashes. This is decomposed by the carbonic acid of the air, the alkali then acts on geine, but this action is greatly assisted by the carbonate of lime. It is perhaps the most powerful agent in the decomposition of the silicate of soda. Here then the action

of carbonates on silicates tells. And it may be worth while to be reminded here, that this action was explained in detail, in order that it might be understood, how spent ashes could act so rapidly on swamp muck.

274. Alkalies and peat, or swamp muck, are within the command of almost every farmer. Lime is not within reach, and besides, requires no small skill in its management. In the preparation of manure, price is every thing. Let the cost be estimated per cord, of artificial manure, prepared in the proportions stated (270). Peat or muck, may be called worth fifty cents per cord, and the labor of digging, say one dollar,

		$1,50
92 lbs. potash, 6 cts.	$5,52	average of alkalies, 3,65
or, 61 lbs. soda ash, or white ash, 4 cts.	2,44	
or, 24 bush. ashes, 12½ cts.	3,00	
	3)10,96	$5,15
	3,65	

Were they really good hard wood ashes, about 16 bushels would be sufficient, but an excess here is allowed, to compensate for variation in quality. This may appear a very high price, but it is to be remembered, that its value is to be compared with that of a cord of clear cow dung. What is the value of cow dung? It appears from the barn account of the Merrimack Manufacturing Company, that for 9 1-2 years, ending October, 1838, a bushel of clear cow dung, costs 21 1-3 cents. During the same time dung of inferior quality was delivered at the Print-works, by the neighboring farmers at 20 cents per bushel. Clear dung, is delivered at the Print-works in Dover at 12 1-2 cents per bushel,

and at several of the Print-works in Rhode Island, at 16 cents per bushel, giving an average of 17·45 cents per bushel, and as a cord contains, in round numbers, 100 bushels, its price is $17,45
Deduct from this the price of an artificial cord, 5,15

$12,30

It is hence evident that an artificial cord is only about one-third of the price of a natural cord, and if the last may be mixed with two parts of loam or swamp muck, so may the first, which will reduce the price of a cord of artificial manure, to $2,71. Now this is equal, according to all experience, cord for cord, to stable manure; the value of that may be estimated at $5, so that an artificial cord costs only about one-half. The best plan for preparing the artificial manure, would be to dig the peat or swamp muck in the fall; in the spring of the year let this be mixed in the proportion of 30 lbs. of potash, or 20 lbs. of soda ash, or 8 bushels of common house ashes, to every cord of fresh dug peat, estimating this by the pit dug out, and allowing nothing in the spring for shrinking. If ashes are used, they may be mixed in at once with the muck, but if soda ash or potashes are used, they must be dissolved in water and the pile evenly wet with the solution. The pile is then to be well shovelled over, and used as is other manure. But it has been found by experience, that the peat may be dug in the spring, immediately mixed with the alkali, and used forthwith. If spent ashes are used to prepare this muck, add one cord of spent ashes to three cords of peat or swamp muck.

275. But there are still other forms of cheap alkali, which may be recommended, though it may appear inconsistent with what has been advanced

respecting lime, but in this case, the lime is converted into a perfectly soluble salt. The soda is eliminated caustic, acts on the geine, renders it soluble. During the exposure to the volumes of carbonic acid, evolved from the peat, the caustic soda becomes carbonated. This carbonate of soda, immediately decomposes the soluble salt of lime, and an insoluble salt of lime with a soluble salt of soda, is the result. The effects of these various actions, are, first, the geine is made soluble, ammonia evolved, which is converted into a nitrate, carbonate of lime produced, which acts as that does in spent ashes, and a soluble salt of soda or common salt remains in the mass, producing still farther good effects, when its alkali is let loose by the action of growing plants. Here are rounds of changes taking place, which though the farmer may not readily understand, he may easily produce, with lime and common salt. It may be stated, in farther explanation of these changes, that common salt is a compound of soda and muriatic acid, or muriate of soda, using here the old language of chemistry, which is more intelligible to the farmer, though not philosophically correct. By mixing quicklime with common salt, its soda is let loose, the acid combines with the lime, forming a soluble salt of lime, and as long as the soda remains caustic it has no effect on the muriate of lime, but as soon as the soda becomes mild or carbonated, decomposition of the muriate of lime is produced, and the common salt regenerated. Commencing then with quicklime and salt, we pass on to a soluble salt of lime and caustic soda, and from that, to mild soda, and to carbonate of lime and the original common salt.

276. If these various changes take place in the midst of peat, or geine, it is evident, that the caustic

soda acts upon the geine, and also evolves ammonia from that substance; secondly, that the muriate of lime in its finely soluble state insinuates itself among all the particles of the geine, that the soda also is equally diffused, and that when the soda becomes carbonated, it produces an almost impalpable carbonate of lime throughout the whole mass, which, by its equal diffusion through the soil with the geine, acts upon the silicates, as has been heretofore explained. In order to produce these effects, take,

1 bushel of salt,
1 cask of lime.

Slack the lime with the brine, made by dissolving the salt in water sufficient to make a stiff paste with the lime, which will be not quite sufficient to dissolve all the salt. Mix all the materials then well together, and let them remain together in a heap for 10 days, and then be well mixed with three cords of peat; shovel well over for about 6 weeks, and it will be fit for use. Here, then, are produced 3 cords of manure, for about the cost of $2,10 per cord.

Salt, ...	$0,60
Lime, ...	1,60
Peat, ...	4,50
	3)$6,30($2,10

From experiments made in a small way, it is believed that this will be found an effectual manure; the author suggests it, in the hope that it may lead to cautious experiment. But there is still another form in which this artificial manure may be prepared—that is by the addition of ammonia, the real Simon Pure of cow dung. Take

3 cords of peat,
61 lbs. sal ammoniac,
1-4 cask, or about 61 lbs. lime.

Slack the lime, dissolve the sal ammoniac, and wet the peat well with the solution through every part. Then shovel over, mixing in the lime accurately. We have here then, 3 cords of manure, at a price as follows:

3 cords peat, ...	$4,50
61 lbs. sal ammoniac, at 1s., . .	10,17
61 lbs. lime, ...	0,27
	3)$14,94($4,98

It will be observed that three cords are used in these calculations, because the quantity of salts used is equivalent to the ammonia in a cord of dung, and that is supposed to be composted with 2 cords of loam, or meadow mud. Whether the estimates are correct, each one will determine by the value he may place on his peat and manure, and can apply his own estimate. When a cord of stable or barnyard manure is usually estimated worth $4, the price of a cord of clear pure cow dung will not be thought high at $17. In fact, it probably, when mixed with the usual proportion of litter, straw, stalks and the usual loss by waste of its value, would become worth only about $5. But these questions do not affect the principle—that from alkali and peat, as cheap a manure may be prepared, and as good, as from stable dung; for let that be called $5,00
then adding 2 cords of peat, 3,00

3)$8,00

$2,66 per cord.

277. There are other sources of alkali, for converting peat into soluble manure. Of these the chief is animal matter. Here we have ammonia produced. It has been actually proved by experiment, that a dead horse can convert 20 tons of peat into a valuable manure, richer and more lasting than stable dung; "a barrel of alewives is equal to a wagon load of peat." The next great and prolific source of ammonia is the urine. The urine of one cow for a winter, mixed up as it is daily collected, with peat, is sufficient to manure 1-2 an acre of land with 20 loads of manure of the best quality, while her solid evacuations, and litter, for the same period, afforded only 17 loads, whose value was only about one-half that of the former.

278. It need only be added in confirmation of all that has been advanced, that those who have had the prudence to fill their yards and hog-pens with meadow mud, which has thus become saturated with ammonia, have in no wise lost their reward. If they have been satisfied with their practice, perhaps they will be no less firm in their belief of success, when science offers them a reason, for the faith that is in them.

279. Having thus considered all the classes of manure, and shown the possibility of enriching barren fields, without the aid of animals, other subjects, intimately connected with this discussion, may be here introduced.

These are, the application of manure in the form of rain, snow, and by overflowing streams, and the humble attempt to imitate these natural processes, by irrigation. The effects in these cases are alike. They are due to two distinct causes, first, to the air of the water, and secondly, to the salts and other materials, dissolved by, or suspended in the water.

First, before it can be understood how irrigation acts, let it be considered, how pure water acts; it is not said rain water, for that acts in a double way, both by its purity and impurity. The more impure, the better manure is water. The purer water is, the less is it fit for irrigation.

280. Pure water acts only by its air. All water exposed to air, absorbs different proportions of its oxygen and nitrogen. This is a very slow process. It is found that most natural waters give out, by boiling, from every hundred cubic inches of water, 3 1-2 cubic inches of air. This air contains 8 or 9 per cent. more oxygen, than an equal bulk of common air. Water is generally filled or saturated with air; it will take up no more by a month's exposure. If this water is boiled, and again exposed to air, it will absorb, in 24 hours, as follows;— Let there be taken any number of measures of air, which are composed of 20 of oxygen and 80 of nitrogen. If 100 measures are absorbed by water, it is in this proportion:

Of Nitrogen, ...	46·43
Of Oxygen, ...	53·57

so that oxygen is three times more absorbable than nitrogen.

281. If now, there is expelled by boiling, the air from pond or river water, it is found to contain,

Nitrogen, ...	45·29
Oxygen, ...	18.63

so that two-thirds of the oxygen have disappeared; this is the only fact which concerns the farmer. The oxygen has been absorbed by natural waters and two-thirds retained. What has become of it? It has gone, it is not said all of it, but in irrigation a large portion to convert insoluble into soluble

geine. Irrigation is chiefly employed on grass-lands. The green sward here may not be broken up—what if it was? What if by ploughing, it was exposed to the action of the air? Remember the properties of geine. Air converts the insoluble to soluble, by forming carbonic acid, that is, the air combines with the carbon of the geine, and forms that gas. Give the geine this oxygen, condensed in water: wet it with this concentrated oxygen, crowd it into geine, as would be done by overflowing a meadow with water. It penetrates every crack and cranny, and every mole's-eye-hole; it expels the carbonic acid imprisoned under the sod. It is doing the same work upon the untouched green sward, which would be effected by ploughing and tillage. The long and the short of the whole action of irrigation with pure limpid water is, that its absorbed oxygen converts insoluble to soluble geine. Is this explanation which science offers, confirmed by practice? The appeal is made to all who have attended either to the theory or practice of irrigation, to bear witness to its truth. Is it not admitted that the running waters are alone fit for this purpose? That after remaining a few days they are abated, and a new flood must cover the land? Is not this necessity of renewing at short periods, the covering of water which shows no deposit, a proof that it has given up some invisible agent to fertilize the earth? This invisible agent is oxygen. Is it not evident from the extreme slowness with which air is absorbed by water, that if it were not for the running water, which every few days replaces that which has acted, that the practice of irrigation with pure water could be never successful?

282. This is the principle—a principle which, having been wholly overlooked, has led to a waste

of time and money, and has given to irrigation, in many minds, the odour, if not of a bad, at least, of a useless practice. Where, guided by this light of science, grass lands can be irrigated, let it be done. If the experience of the most enlightened agriculturists in Europe is not all deception, by simple irrigation with running water, the farmer may cut two tons of hay where he toils and sweats to rake off one.

183. But by far the most fertile source of increased crops by irrigation, is found in the impurity of water; the salts and suspended matter, the slime and genial mud of freshets. Perhaps the effect due to this cause, cannot be better illustrated, than by a statement of those substances, and their amount, which fill the waters of the Merrimack; a flood of blessings! which rolls by those engaged in the din and hot haste of manufactures, as unheeded as was the earthquake which thundered and trembled, and rolled away under the feet of the fierce soldiery in an ancient battle. In the year 1838, during twenty-three days of freshets, from May till November, no less than 71,874,063 lbs. of geine and salts rolled by the city of Lowell, borne seaward. During the five days of the great freshet, from January 28th to February 1st, 1839, no less than 35,970,897 lbs. of the same matter rolled by at from the rate of 112,128 lbs. to 20,405,397 lbs. per day; each cubic foot of water bearing onwards, from 1 1-2 to 30 1-2 grains. This is only the suspended matter. That which is chemically dissolved by the waters, the fine filmy deposit, which occurs in a few days after the coarser and grosser matters subside—and the matter ordinarily suspended in the water of the river added to the above for the year 1838, give a grand total of 839,181 tons of salts

and geine, which were rolled down in the water of the Merrimack river.

284. What is this matter? Is it of any agricultural value? The answer to the first question will answer both. The dissolved salts are sulphate and geate of lime, and the fine deposit occurring after the water has settled, is composed of one-half geine, and the remainder of salts of lime and silicates. The great agricultural value is found in the clayey deposit, which occurs in the first few days. The coarser part, that which collects about the foot of rocks, and falls, and eddies is composed, as follows:

Geine,	3.92
Silex,	72·70
Oxide of iron,	9·15
Alumina,	8·30
Lime,	0·51
Magnesia,	0·10

But considering the elements as we have usually treated them, as silicates, salts and geine, the composition of the several deposits is shown in the following table:

	Geine.		Sulphate of lime.	Phos. of lime.	Silicates.
	Soluble.	*Insol.*			
The coarse deposit above,	2·06	1·86	0·74	0.90	94·44
Freshet, 1839,	5·40	6·50	2·34	1·20	84·66
Freshet, July 7—18, '39,	8·80	6·30	3·20	0·60	81·20

285. If the doctrine of the action of silicates, salts and geine, upon each other when aided by growing plants, is considered, it cannot fail to be perceived, that the fertility of soils, periodically overflowed by turbid waters, is owing to the ele-

ments, salts and geine which it contains, and to the exquisitely finely divided state of the silicates which form the bulk of the deposit. The carbonic acid of the air, acts on each atom of silicate, while owing to the geine, having been, as it were, irrigated, the oxygen of the air and water, must put that into a state to evolve carbonic acid. Hence, the silicates are at once decomposed, and their alkali liberated. How beautiful! It seems like a special interposition of that beneficent Power, whose blessings, while they fill us with wondering admiration, at the infinite skill, which directs every change in the material universe, should teach us also, that these changes are held up to us, not only to admire, but in some humble degree to imitate. Whenever man —"the faithful servant and interpreter of nature," has thus learned the lessons propounded by an Infinite Mind, he finds, when he humbly imitates nature's laws, she is a kind and indulgent parent. She opens her hand liberally, and gives fertility by irrigation, and rivers and streams like holy water, sprinkled by a reverend father, fructify all they bedew. With hearts thus attuned, by the observation of the laws of nature, they respond to the gentle vibrations, caused by the descent of genial and fertilizing showers.

286. Rain is only natural irrigation; the water is found like that of rivers, rich in oxygen, and organic matter. The fertilizing power of rain, is referred to the same causes, which lead to irrigation, to the salts and geine, which rain water contains. Several chemists have proved the existence of saline matters and organic substances in the air. The falling rain carries down with it salts of ammonia, of soda, of lime, and organic matter.—These all may be supposed floating in the air. The

dry soils, give to the winds an impalpable dust, its silicates and geine. When hailstones which have been formed in the regions of perpetual frost, exhibit almost the same substances, which are contained in rain water, the height at which these matters float, would almost compel the supposition that they exist in a gaseous state. From the examination of hailstones, by Girardin, a French chemist, it appears, that no sensible trace of ammonia was detected during the evaporation of their water, but there was found a notable quantity of lime and sulphuric acid; and above all, a large proportion of an organic substance containing nitrogen. Melted hailstones have the appearance of water, containing a drop or two of milk; by standing, the water grows clear, and the flocky matter which settles, burns with the smell of animal matter, and evolves ammonia.

It is a question whether, even at the Giessen Laboratory this was not the source of the ammonia, there discovered in rain water. It is taken for granted, that the ammonia in rain water existed as a volatile carbonate, because it was found to pass over in distillation. So did a volatile product, which always discoloured the crystals of sal ammoniac, procured by adding muriatic acid to the distilled water. This discolouring matter, was noticed a century ago by Margraf. Later chemists have also detected ammoniacal salts in rain water, but no volatile carbonate of that base. It is well known that muriate of soda arises in evaporation, so does chromate of potash, and several other salts. If in distilling rain water, the ammonia did not pass over in the volatile organic discolouring product, it may have gone over as muriate of ammonia. It is not questioned that ammoniacal salts exist in rain and

snow water. The fact that it there exists as carbonate, seems to be assumed, and is incompatible with the salts which have been heretofore obtained, from rain, snow and hail. This subject has of late excited much attention, and as the existence of salts in snow, is intimately connected with the old saying, that "snow is the poor man's manure," it may be worth while to examine the foundation of this proverb. Like all others of this class, it will be found to rest on observation, and is supported by experiment. In 1751, Margraf, in the neighborhood of Berlin, after it had snowed several hours, collected in glass vessels, as much falling snow as afforded 3600 ounces of water. This carefully evaporated, afforded 60 grains of calcareous matter, with some grains of muriatic acid, and traces of nitrous vapor. An equal quantity of rain water, afforded 100 grains calcareous matter, with some muriatic acid; and in both cases the matter was discolored by an oily substance. A similar result was obtained long ago in Ireland, by Dr Rutty, who found in a gallon of snow water, 4 grains, and in one gallon of rain water, 6 grains of calcareous matter. This is about the proportion found by Margraf, and would give for each inch of snow water about 10 lbs. of salts per acre. From the existence of free acids in this case, it is evident that no carbonate of ammonia could have there existed. There are some experiments performed by our countryman, Dr. Williams, formerly Hollis Professor of Mathematics and Natural Philosophy in Harvard College, and detailed in the first volume of his history of Vermont, where the experiments were performed. In 1791, 6 gallons of fresh falling snow water, afforded by evaporation, 11 grains calcareous matter, 2 grains of saline matter, 5 grains of a dark brown oily matter.

In January, 1792, 6 gallons of snow water, from snow lying three inches deep on the grass, on an area of 16 square feet, where it had lain 59 days, covered with a depth of 27 inches of snow, afforded the same salts as above, and 105 grains of this oily matter. This is the most remarkable fact, and may afford some weight to the suggestion before made, that organic matter exists gaseous in the air. It must have been drawn up by capillary attraction, or evolved from the surface of the earth. It is there condensed by the snow, and returned to the earth, impregnated with its salts of lime and ammonia.—The snow is "the poor man's manure." It not only adds salts and geine, but prevents the escape of the last. But is it possible that it should escape in the cold? Doubtless it does when the ground is not frozen. The snow by its warm mantle actually prevents the earth growing colder, and as has been ingeniously suggested, keeps up an imperfect vegetation. The snow thaws frozen ground. In 1791, Professor Williams found that the ground which had been frozen 6 inches in depth, before the snow fell, not only had this frost extracted in a few weeks by snow, but that the ground, 6 inches below the surface, had a temperature of 39 degrees. This slight elevation of temperature was enough to allow the gaseous exhalation of organic matter, which was found to exceed that of fresh fallen snow, by 20 times. This quantity in snow 3 inches deep, would give per acre 40 lbs., and to this are to be added 5 lbs. of salts. If this geine is not a natural addition in weight, it has undergone a transformation and become soluble. Besides, every inch of fresh fallen snow actually adds a little of this same matter; it will not be extravagant to estimate the total addition of geine at 50 lbs. per acre for the winter.—

This added to the warming effects of snow, shows that it may have a genial and enriching power on vegetation, independent of its ammonia. The old notion of the existence of nitre in snow is not supported by evidence; but in whatever view we consider the salts of lime, in snow and rain water, it is difficult to believe that carbonate of ammonia exists in atmospheric air.

287. There are still other sources of manure, or the elements of fertility, which the farmer can command. Among these, are paring and burning, and the ploughing in of green, and dry crops.

It is not intended to go into the detail of these operations. All experience proves their great fertilizing power. Their whole action, mysterious as a part of it may appear, depends for its success upon the formation of geine, salts, and silicates. And first,—burning, in which is to be considered the effects of simply burning the earthy parts of soils. In the description of silicates, Chap. II, the frequent occurrence of pyrites, or sulphuret of iron, was described, and this is especially the case in all clays. The effect of burning is, to disengage sulphurous acid, and the red and seared appearance of the foliage in the neighborhood of a brick kiln, which may be often observed, is due to the disengagement of acid gases, during the process of burning the bricks. This acid gas being liberated, in the operation of burning soils, hastens the formation of sulphates and salts. It divides the silicates, and thus reduces them to a state in which the carbonic acid of the air more easily decomposes them. If we go one step further, and burn the vegetable matter of the soil, a portion of geine is lost, and ashes are formed, whose operation has been already considered, Chap. III. They dissolve any geine in soil,

hence the practice of burning the parings of a peat meadow, whose ashes, bring the balance into cultivation. The whole practice of burning vegetable soil for its ashes, is wasteful. The original mode of paring and burning, and which forty years ago was so common in Europe, is still followed in many places in England, where the paring, from the operation, is called push ploughing. It has been more often given up, from the excessive crops it has produced, exhausting the soil, than any inherent sin in the practice itself. Instead of paring and burning, it should rather be called paring and roasting. The process should never go beyond a good scorching. The effects of scorching insoluble geine, and inert vegetable fibre, may be illustrated by reference to the effects of roasting coffee or rye. A tough green berry, or dry seed, which is quite insoluble, is made by this process very soluble. Toasting bread has a like effect, and so has baking, on the dough.—Though in roasting coffee, a large portion of charcoal seems to be made, yet in the grounds of coffee, vegetable fibre is in that state, in which air and moisture act, as they do on the geine of soils, converting the insoluble into soluble. If ever decided good effects have been witnessed from the application of charcoal, independent of rain water, they are due to the cause here pointed out.

188. Turning in green crops is returning only to the soil, the salts, silicates and geine, which the plant has drawn out of it, together with all the organic matter, the plant itself has elaborated, from oxygen and hydrogen, carbon, and nitrogen, from whatever source derived. It has decomposed, during the short period of its growth, as has been already pointed out, more silicates and salts, than the air only, could effect during the same period, which

being turned in, restore to the soil from which they grew, salts and silicates in a new form, whose action on vegetation is like that of alkalies. But, powerful as are the effects of green crops, ploughed in, it is the experience of some práctical men, that one crop allowed to perfect itself and then die where it grew, and then turned in dry, is superior to three turned in green. The whole result is explained by the fact, that dry plants give more geine than green. Green plants ferment,—dry plants decay. A large portion escapes in fermentation as gas and more volatile products are formed, than during decay. The one is a quick consuming fire, the other a slow mouldering ember, giving off during all its progress, gases, which feed plants, and decompose the silicates of soil.

289. The power of fertility which exists in the silicates of soil is unlimited. An improved agriculture must depend upon the skill with which this power is brought into action. It can be done only by the conjunction of salts, geine and plants. Barren sands are worthless, a peat bog is little better; but a practical illustration of the principles, which have been maintained, is afforded by every sandy knoll, made fertile by spreading swamp muck upon it. This is giving geine to silicates. The very act of exposure of this swamp muck, has caused an evolution of carbonic acid gas; that decomposes the silicates of potash in the sand; that potash converts the insoluble into soluble manure, and lo! a crop. That growing crop, adds its power to the geine. If all the long series of experiments under Von Voght, in Germany, are to be believed, confirmed as they are by repeated trials by our own agriculturists, it is not be doubted, that every inch of every sand knoll, on every farm, may be changed into a soil

in 13 years, of half that number of inches of good mould.

290. That the cause of fertility, is derived from the decomposing power of the geine and plants, is evident from the fact, that mere atmospheric exposure of rocks, enriches all soil lying near and around them. It has been thought among the inexplicable mysteries, that the soil under an old stone-wall is richer than that a little distance from it. Independent of its roller action, which has compressed the soil and prevented the aerial escape of its geine, consider that the potash washed out of the wall has done this, and the mystery disappears. The agents to hasten this natural production of alkali, are salts and geine. The abundance of these has already been pointed out in peat manure. Next to this, dry crops ploughed in; no matter how scanty, their volume constantly will increase, and can supply the place of swamp muck. Of all soils to be cultivated, or to be restored, none are preferable to the sandy light soils. By their porousness, free access is given to the powerful effects of air. They are naturally in that state, to which trenching, draining, and subsoil ploughing are reducing the stiffer lands of England. Manure may as well be thrown into water, as on land underlaid by water. Drain this, and no matter if the upper soil be almost quicksand, manure will convert it into fertile arable land. The thin covering of mould, scarcely an inch in thickness, the product of a century may be imitated by studying the laws of its formation. This is the work of "Nature's 'prentice hand;" man has long been her journeyman, and now guided by science, the farmer becomes the master workman, and may produce in one year, quite as much as the apprentice made in seven.

CHAPTER VIII.

PHYSICAL PROPERTIES OF SOIL.

291. In all attempts at improving soil by manure, two objects are intended, which form the golden rule of applying salts and geine; to make "heavy land lighter, light land heavier, hot land colder, and cold land hotter." Are there then, notwithstanding all that has been offered and said, differences in soil? Have not, it may be asked, all the preceding pages been based on the fact, that there is but one soil? True it has been so said, it is said so now. Chemically, the inorganic elements of all soil are alike. The silicates and salts are nearly the same in all; the organic portion, the geine varies, and that to a greater degree, than any other ingredient. While the silicates compose with great uniformity, from 80 to 90 per cent., and the salts of lime, sulphate, and phosphate, from 1-2 to 3-4 per cent., the geine varies from 1 to 20 per cent. The silicates may be finer or coarser, more sandy or more clayey. All these circumstances, affect, not the chemical, but the physical properties of soil. The physical properties then, are the foundation of the great diversity which soil exhibits. The subject of soil, will be very imperfectly treated, if a few pages are not devoted to this important subject. The physical characters of soil, are embraced under the

terms, cold, hot, wet, and dry land. These characters are dependent on four circumstances.

292. First, the absolute weight of a given bulk of soil,
Secondly, its colour,
Thirdly, its consistency,
Fourthly, its power of retaining water.

In other words, the physical characters of soil may be considered under—
First, its relation to heat,
Secondly, its relation to moisture and gas,
Thirdly, its consistency,
Fourthly, its electrical relation.

The relation to consistency makes soil light, or heavy; the relation to heat and moisture, makes soil hot or cold, dry or wet. The great natural varieties of soil are, sand, clay, and loam; first, the great distinction in the scale of soil, is sand and clay: all intermediate varieties proceed from mixtures of these, with each other. Now the sand may be siliceous, or calcareous—that is, silicates, the distinguishing character of soil in this country, or mixed with a salt of lime, the feature of much European soil. By clay is meant common blue clay, or sub-silicate of alumina, consisting of alumina, 36; silica, 68; oxide of iron, and salts of lime, and alkalies, 6.

Sandy clay is—clay and sand, equal parts.
Loamy clay is—3-4 clay, and 1-4 sand.
Peaty earth is—geine.
Garden mould is—8 per cent. geine.
Arable land is—3 per cent. geine.

Taking these several varieties, it is found, that sand is always the heaviest part of soil, whether dry or wet; clay is among the lightest part; geine has the least absolute weight, so that while a cubic

of sand weighs, in its common damp state, 141 lbs., clay weighs 115 lbs., and geine 81 lbs.; hence garden mould and arable soil weigh from 102 to 119 lbs. The more geine, compound soil contains, the lighter it is.

293. Among the most important physical characters of soil, is the power of retaining heat; this will be found to be nearly in proportion to its absolute weight. The weight of soil, determines with tolerable accuracy, its power of retaining heat. The greater the mass in a given bulk, the greater is this power. Hence sands retain heat longest, three times longer than geine, and half as long again as clay. Hence, the dryness and heat of sandy plains. Sand, clay, and peat, are to each other as 1, 2, and 3 in their power of retaining heat. But while the capacity of soil to retain heat, depends on the absolute weight, the power to be warmed, another very important physical character depends on four principal circumstances: first, the colour; second, the dampness; third, the materials; fourth, the angle at which the sun's rays fall. First colour, the blacker the colour, the easier warmed. White sand and gray, differ almost 50 per cent., in the degree of heat acquired in a given time. As peat and the varieties of geine, are almost all of a black, or dark brown colour, it is seen how easily they may become warm soils, when dry; for secondly, dampness modifies the influence of colour, so that a dry, light colored soil will become hotter, sooner than a dark wet one. As long as evaporation goes on, a difference of 10 or 12 degrees will be found between a dry and a wet soil of the same colour. Thirdly, the different materials of which soils are composed, exert but very little influence on their power of being heated by the sun's rays. Indeed,

if sand, peat, clay, garden mould, all equally dry, are sprinkled with chalk, making their surfaces all of a color, and then exposed to the sun's rays, the differences of their temperature, will be found inconsiderable. Colour and dryness then, exert a most powerful influence on the capacity of soil to be warmed.

Fourthly, the last circumstance to be noticed, is the different angle at which the sun's rays fall. The more perpendicular, the greater the heat. The effect is less in proportion, as these rays by falling more slanting, spread their light out over a greater surface. But this point, which seems external to soil, need not be enlarged on. Now, the great fact to be observed, in this relation, of soil to heat is, that geine exerts the most marked influence. If soil heats quickly, it is because it has a large proportion of geine. Does it cool quickly? it is the geine which gives up heat quickly, referring here to the soil in a dry state, the modification produced by dampness, having been already considered.

294. The relation of soil to moisture and gas, is not less important than that of heat. All soil, except pure siliceous sands, absorb moisture, but in different degrees. Geine possesses the greatest power of absorption, and no variety of geine equals in its absorptive power, that from animal manure. The others rank in the following order, garden mould, clay, loam, sandy clay, arable soil. They all saturate themselves with moisture by a few days' exposure. It is a very interesting question, does soil give up this absorbed water speedily and equally? Is its power of retaining water equal? As a general fact, it may be stated, that the soil which absorbs fastest and most, evaporates slowest and least. Geine evaporates least in a given time. The pow-

er of evaporation, is modified by the consistence of soil; by a different degree of looseness or compactness of soil. Garden mould, for instance, dries faster than clay. As it has been already shown, that the power of being warmed is much modified by moisture, so the power of a soil to retain water makes the distinction of a hot or cold, wet or dry soil. In all the relations to moisture, as to heat, geine exercises the greatest influence.

295. Connected with this power of absorption of moisture, is the very important relation of soil to gas. All soil absorbs oxygen gas, when damp, never when dry. Of the ingredients of soil, geine forms the only exception to this rule. That absorbs oxygen, whether it be wet or dry. Geine has this power in the highest degree, clay next; frozen earths not at all. A moderate temperature increases the absorption.

When earths absorb oxygen, they give it up unchanged. They do not combine with it. They merely induce on the absorbed moisture, power to imbibe oxygen. But when geine absorbs oxygen, one portion of that combines with its carbon, producing carbonic acid, which decomposes silicates, and a second portion of oxygen combines with the hydrogen of the geine, and produces water. Hence, in a dry season well manured soils or those abounding in geine, suffer very little. The power of geine to produce water, is a circumstance of soil almost wholly overlooked. It is one, whose high value will appear by a comparison with the quantity of water, produced by a fresh ploughed, upturned sward, with that from the same soil undisturbed. The evaporation from an acre of fresh ploughed land is equal to 950 lbs. per hour; this is the greatest for the first and second days, ceases about the

fifth day, and again begins by hoeing, while at the same time the unbroken sod affords no trace of moisture. This evaporation is equal to that which follows after copious rains. These are highly practical facts, and teach the necessity of frequent stirring of soil in a dry time. Where manure or geine is lying in the soil, the evaporation is from an acre, equal, to 5000 lbs. per hour. At 2000 lbs. of water per hour, the evaporation would amount in 92 days to 2,208,000 lbs. which is nearly equal to the amount of rain which would fall in the same time in this climate. But the evaporation from woodland actually exceeds the amount of rain which falls. The evaporation from an acre of woodland was determined by Professor Williams, (see his Hist. of Vermont, vol. I,) as follows: two leaves and a bud of a branch of a growing maple were sealed in a bottle, while yet attached to the tree. The expired water, collected, and weighed, was found to amount in six hours to 16 grains. The tree was 8 1-2 in. in diameter, and 30 feet high. It was felled, and the leaves carefully counted, were in number, 21,192. Supposing these all to have evaporated like those in the bottle, they would have expired, in twelve hours, 339,072 grains of water. A moderate estimate, and below the usual quantity of wood per acre of similar land, gave four such trees to a rod, or 640 per acre. Estimating 7000 grains to a pint, 3,875 gallons of water, or 31,000 lbs. were evaporated from an acre of woodland in 12 hours. At Rutland, in Vermont, where this experiment was made, in 1789, the Professor notes, that on the 26th of May, the maple leaves were 1-6 of their full size, and on the 15th of September following, these leaves began to turn white. Throwing out the 15 days in Septem-

ber and the 4 in May, the leaf may be considered as fully developed for three months. During these 92 days, the evaporation would have amounted, at 12 hours per day, to 2,852,000 lbs. The rain at the place during this period, was 8,333 inches or 43 4-10 of a pound to every square foot of surface, equal per acre of 43,560 feet, to 1,890,504 lbs. The amount of evaporation during the time in which the tree was in full leaf exceeds that of the actual fall of rain, by nearly 1,000,000 of lbs. This excess arises from the decomposition of geine in the soil, and consequent formation of water, by the action of the living plant. If we allow the process to go on, during 15 hours per day, then in 92 days, as above, 3,565,000 lbs. of water would be evaporated. One may easily understand how exhausting a process must be vegetation, where every year, all above ground is cut and carried away. Not only the geine, whose carbon and water, have become parts of the plant is thus withdrawn, but a still larger portion, disappears as water and carbonic acid. In forests, the annual fall of leaves and wood, in fields, the ungathered crop, may add more than the amount thus withdrawn from soil. That plants do form from carbonic acid and water, a great amount of vegetable matter, is by all admitted. This amount in dry or green crops turned in, increases the geine of soil.

There is yet another view of the effect of the conversion of geine into water. Allowing, as has been asserted, that all land, forest or cultivated, produces annually about the same amount of carbon, then the amount of water, transpired above from woodland in 15 hours, is nearly equal to dissolving one-half of the geine, to produce that amount leaving the balance to be derived from air. An

acre of woodland produces, it is said, annually, about 1783 English pounds of carbon. If water dissolves only $\frac{1}{2500}$ part of its weight of humus or geine, then 3,565,000 dissolve 1426 lbs., which, at 58 per cent carbon are equal to . . . . 827 lbs.
Leaving to be derived from air, . . . 956 lbs.

1783 lbs.

This is taking geine in its most insoluble state. The great increase of solubility when combined with alkali would render the annual amount of water transpired, equal to dissolving, as geine, all the carbon which has been added to the plant.

The advantage of a light porous open soil is now evident; it lets in air, it lets off steam. This steam charged with carbonic acid, acts on silicates, eliminates alkalies, waters and feeds plants. Salts, geine, and barren pine plains, are the elements of a western prairie. Nature never bestowed upon man, soil of greater capability of being made lastingly fertile, than the sandy light soil of New England.

296. It is evident that the terms of heavy and light, given by the farmer to soil, do not refer to their absolute weight (293). These distinctions depend on firmness or consistency of soil. This produces a very marked difference in the fertility and tillage of land. The terms light and heavy, mean lighter or heavier to work. It is well known clay lands are heavy to work, sandy soil is the lightest and easiest, next to this is a soil containing a small portion of geine. All light soil becomes heavy when wet, but it is a well ascertained fact, that heavy soil always becomes lighter by frost. Hence the reason of breaking up with a plough be-

fore winter. Moist earth then becomes frozen, and its particles being driven asunder by frost, it becomes lighter—in truth it has been found, that the consistency of clay, is diminished nearly one-half by frost, and loamy clay, one-half to two-thirds. It is essential to this change from heavy to light land, that the soil be wet enough to freeze. It is well known, that if by frost, the nature of the soil is thus changed, that if it is ploughed while wet after freezing, the labor of the fall ploughing is lost. A lasting injury is done by ploughing land too wet.

297. In reference to the electrical relations of soil, the dry sands are non-conductors, the clays weak imperfect conductors, they are in the negative state. Geine is always positive towards the elements of soil.

298. In whatever view we regard geine, it is the basis on which rests the whole art of agriculture. It is this which causes the great difference of soil. It is a difference of physical characters. The chemical characters are uniform. If then, geine is the soul of fertility, if it makes soil, hot, cold, wet, dry, heavy or light, the proportion in which it exists in soil, becomes an agricultural problem of the highest value. This would lead to chemical analysis. The lectures in which the principles set forth in this book, were explained, terminated with a practical exhibition of the process of analysis of soil. Having already greatly exceeded the limits to which it was intended to confine these pages, the subject of analysis, and several other topics may be resumed at some other time.

APPENDIX.

No. 1.—*Dr. Nichols's Statements, from the Essex County Agricultural transactions*, 1839—40.

To the Committee to whom was referred the communication of Andrew Nichols, on the subject of Compost Manures, &c.

GENTLEMEN:—Persuaded of the importance of the discoveries made by Dr. Samuel L. Dana, of Lowell, and given to the world through the medium of the reports of Professor Hitchcock and Rev. H. Colman, to the Legislature of Massachusetts, concerning the food of vegetables, geine, and the abundance of it in peat mud, in an insoluble state to be sure, and in that state not readily absorbed and digested by the roots of cultivated vegetables, but rendered soluble and very easily digestible by such plants by potash, wood ashes, or other alkalies, among which is ammonia, one of the products of fermenting animal manures, I resolved last year to subject his theories to the test of experiment the present season. Accordingly I directed a quantity of black peat mud, procured by ditching for the purpose of draining and reclaiming an alder swamp, a part of which I had some years since brought into a state highly productive of the cultivated grasses, to be thrown in heaps. During the winter I also had collected in Salem, 282 bushels of unleached wood ashes, at the cost of 12 1-2 cents per bushel. These were sent up to my farm, a part to spread on my black soil grass lands, and a part to be mixed with mud for my tillage land. Two hundred bushels of these were spread on about six acres of such grass land, while it was covered with ice and frozen hard enough to be carted over without cutting it into ruts. These lands produced from one to two tons of good merchantable hay to the acre, nearly double the crop produced by the same lands last year. And one fact induces

me to think, that being spread on the ice, as above mentioned, a portion of these ashes was washed away by the spring freshet. The fact from which I infer this, is, that a run below, over which the water coming from the meadow on which the largest part of these ashes were spread flows, produced more than double the quantity of hay, and that of a very superior quality to what had been ever known to grow on the same land before.

Seventy bushels of these ashes, together with a quantity not exceeding thirty bushels of mixed coal and wood ashes made by my kitchen and parlor fires, were mixed with my barn manure, derived from one horse kept in stable during the winter months, one cow kept through the winter, and one pair of oxen employed almost daily on the road and in the woods, but fed in the barn one hundred days. This manure was never measured, but knowing how it was made, by the droppings and litter or bedding of these cattle, farmers can estimate the quantity with a good degree of correctness. These ashes and this manure were mixed with a sufficient quantity of the mud above mentioned by forking it over three times, to manure three acres of corn and potatoes, in hills four feet by about three feet apart, giving a good shovelfull to the hill. More than two-thirds of this was grass land, which produced last year about half a ton of hay to the acre, broken up by the plough in April. The remainder was cropped last year without being well manured, with corn and potatoes. Gentlemen, you have seen the crop growing and matured, and I leave it to you to say whether or not the crop on this land would have been better had it been dressed with an equal quantity of pure, well rotted barn manure. For my own part, I believe it would not, but that this experiment proves that peat mud thus managed, is equal if not superior to the same quantity of any other substance in common use as a manure among us; which, if it be a fact, is a fact of immense value to the farmers of New England. By the knowledge and use of it, our comparatively barren soils may be made to equal or excel in productiveness the virgin prairies of the West. There were many hills in which the corn first planted was destroyed by worms. A part of these were supplied with the small Canada corn, a part with beans. The whole was several times cut down by frost. The produce was three hundred bushels of ears of sound corn, two tons of pumpkins and squashes, and some

potatoes and beans. Dr. Dana, in his letter to Mr. Colman, dated Lowell, March 6, 1839, suggests the trial of a solution of geine as a manure. His directions for preparing it are as follows: "Boil one hundred pounds of dry pulverized peat with two and a half pounds of white ash, (an article imported from England,) containing 36 to 55 per cent. of pure soda, or its equivalent in pearlash or potash, in a potash kettle, with 130 gallons of water; boil for a few hours, let it settle, and dip off the clear liquid for use. Add the same quantity of alkali and water, boil and dip off as before. The dark colored brown solution contains about half an ounce per gallon of vegetable matter. It is to be applied by watering grain crops, grass lands, or any other way the farmer's quick wit will point out."

In the month of June, I prepared a solution of geine, obtained not by boiling, but by steeping the mud as taken from the meadow, in a weak ley in tubs. I did not weigh the materials, being careful only to use no more mud than the potash would render soluble. The proportion was something like this: peat 100 lbs., potash 1 lb., water 50 gallons—stirred occasionally for about a week, when the dark brown solution described by Dr. Dana, was dipped off and applied to some rows of corn, a portion of a piece of starved barley, and a bed of onions sown on land not well prepared for that crop. The corn was a portion of a piece of manured as above mentioned. On this the benefit was not so obvious. The crop of barley on the portion watered, was more than double the quantity both in straw and grain to that on other portións of the field, the soil and treatment of which was otherwise precisely similar.

The bed of onions which had been prepared by dressing it with a mixture of mud and ashes previous to the sowing of the seed, but which had not by harrowing been so completely pulverized, mixed and kneaded with the soil, as the cultivators of this crop deemed essential to success, consisted of three and a half square rods. The onions came up well, were well weeded, and about two bushels of fresh horse manure spread between the rows. In June, four rows were first watered with the solution of geine above described. In ten days the onions in these rows were nearly double the size of the others. All but six rows of the remainder were then watered. The growth of these soon outstripped the unwatered remainder.

Mr. Henry Gould, who manages my farm on shares, and who conducted all the foregoing experiments, without thinking of the importance of leaving at least one row unwatered that we might better ascertain the true effect of this management, seeing the benefit to the parts thus watered, in about a week after, treated the remainder in the same manner. The ends of some of the rows, however, which did not receive the watering produced only very small onions, such as are usually thrown away as worthless by cultivators of this crop. This fact leads me to believe that if the onions had not been watered with the solution of geine, not a single bushel of a good size would have been produced on the whole piece. At any rate, it was peat or geine rendered soluble by alkali, that produced this large crop.

The crop proved greater than our most sanguine expectations. The onions were measured in the presence of the chairman of your committee, and making ample allowance for the tops which had not been stripped off, were adjudged equal to four bushels to the acre. In these experiments, 7 lbs. of potash which cost 7 cents a pound, bought at the retail price were used. Potash, although dearer than wood ashes at 12½ cents per bushel, is, I think cheaper than the whitewash mentioned by Dr Dana, and sufficiently cheap to make with meadow mud, a far cheaper manure than such as is in general used among our farmers. The experiment satisfies me that nothing better than potash and peat can be used for most if not all our cultivated vegetables, and the economy of watering with a solution of geine, such as are cultivated in rows, I think cannot be doubted. The reason why the corn was not very obviously benefitted, I think, must have been, that the portion of the roots to which it was applied, was already fully supplied with nutriment out of the same kind from the peat ashes and manure put in the hill at planting. For watering rows of onions or other vegetables, I should recommend that a cask be mounted on light wheels, so set that like the *drill* they may run each side of the row and drop the liquid manure through a small tap hole or tub from the cask, directly upon the young plants. For preparing the liquor, I should recommend a cistern about three feet deep and as large as the object may require, formed of plank and laid on a bed of clay and surrounded by the same, in the manner that tan vats are constructed;

this should occupy a warm place, exposed to the sun, near the water, and as near as these requisites permit to the tillage lands of the farm. In such a cistern in warm weather, a solution of geine may be made in large quantities with little labor and without the expense of fuel, as the heat of the sun is, I think, amply sufficient for the purpose. If from further experiment it should be found economical to water grass lands and grain crops, a large cask or casks placed on wheels and drawn by oxen or horse power, the liquor from the casks being at pleasure let into a long narrow box perforated with numerous small holes, which would spread the same over a strip of ground, some 6, 8, or 10 feet in breadth, as it is drawn over the field in the same manner as the streets in cities are watered in summer.

ANDREW NICHOLS.

I certify that I measured the piece of land mentioned in the foregoing statement, as planted with corn, on the 21st of September, 1839, and found the same to contain two acres, three quarters, thirty-one rods.

JOHN W. PROCTOR, Surveyor.

Dr. Andrew Nichols's Statement of 1840.

GENTLEMEN:—Having invited the attention of the Trustees of the Essex Agricultural Society to our continued use of, and experiments on, fresh meadow or peat mud, as a mauure, it is of course, expected that the result of these experiments should be laid before them. The compost with which we planted most of our corn and potatoes the present year, was composed of the same materials, and managed in the same manner as that which wa used last year for the same purpose.

Four acres of corn, on the same kind of soil, was manured in the hill with this compost, and one acre of corn on a more meagre portion of the same field, was manured in the same manner, with a compost consisting of the same kind of mud, half a cord of manure taken from the pigsty, and forty pounds of potash, second quality, dissolved in water, sprinkled over and worked into the heap,

with the fork, in the same manner that the dry ashes were into the other compost. Of both kinds the same quantity, a common iron or steel shovel full to the hill, was used, and no difference in the crop which could be ascribed to the different manures, could be perceived. The hills were four by three feet apart on an average. In the borders and adjoining this piece of corn, one acre was planted with potatoes. The compost used in some portions of this consisted of rather a larger portion of coarse barn manure composed of meadow hay, corn fodder waste, &c., wet with urine and mixed with the droppings of cattle, and less meadow mud. The whole six acres was hoed twice only after the use of the cultivator. The whole amount of labor after the ground was furrowed and the compost prepared in heaps on the field, is stated by the tiller of the ground, H. L. Gould, to have been forty-nine day's work of one man previous to the cutting of the stalks. Pumpkins, squashes, and some beans were planted among the corn. The produce was four hundred and sixty bushel baskets of sound corn, eighty bushels of potatoes, three cords of pumpkins, one and a half bushels of white beans. On one acre of the better part of the soil, harvested separately, there were one hundred and twenty baskets of corn ears, and a full proportion of the pumpkins. On one-eighth of an acre of Thorburn's tree corn treated in the same manner as the rest, the produce was nineteen baskets. A basket of this corn shells out seventeen quarts, one quart more than a basket of the ordinary kinds of corn. The meal for bread and puddings is of a superior quality. Could we depend upon its ripening, for, Thorburn's assertions to the contrary notwithstanding, it is a late variety of corn, (though it ripened perfectly, with us last season, a rather unusually warm and long one,) farmers would do well to cultivate it more extensively than any other kind.

The use of dry ashes on our black soil grass lands showed an increased benefit from last year. But our experiments with liquid manure disappointed us. Either from its not being of the requisite strength, or from the dryness of the season, or from our mistaking the effects of it last year, or from all these causes combined, the results confidently anticipated, were not realized; and from our experiments this year we have nothing to say in favor of its use, although we think it worthy of further ex-

periments. On the first view of the subject, a dry season or a dry time might seem more favorable to the manifestations of benefit from watering plants with liquid manure, than wet seasons or times. But when we consider that when the surface of the earth is dry, the small quantity of liquid used would be arrested by the absorbing earth ere it reached the roots, and perhaps its fertilizing qualities changed, evaporated, or otherwise destroyed, by the greater heat to which at such times it must be exposed—it is not, I think, improbable that the different effects noticed in our experiments with this substance, the two past years, might be owing to this cause. It is my intention, should sufficient leisure permit, to analyze the soil cultivated and the mud used, and prepare a short essay on the subject of peat mud, muck, sand, &c., as manure, for publication in the next volume of the transactions of the society.

Yours, respectfully,

ANDREW NICHOLS.

Danvers, December 20, 1840.

No. II—*Extract from Dr. Nichols's Letter.*

DANVERS, JAN. 28, 1842.

DEAR SIR:—I am sorry to say that I have no new facts to communicate. Nor have I any thing that contradicts my former views on the subject of peat, as manure. We used it in compost on about nine acres of corn and potatoes last summer, one-half of which was the same land on which it was used the preceding season. Its effect seemed not to be lessened by this second trial in the same soil. The compost was as formerly composed by mixing the mud, barn manure, ashes or potash together in the field, in spring, two or three weeks before the corn was planted; in a part of it, say, the manure for two acres, about 20 lbs. of nitrate of potash were used. Wherever the nitre was used, worms were absent; other parts of the field were more or less injured by them. This was all the good that we could positively ascribe to the nitre. Our crops were in a most flourishing condition on the morning of the 30th of June, in the afternoon and evening

of that day, a violent tempest and two showers of hail, blew down my barn, half my fruit trees, and prostrated and mangled the corn. I should have bargained readily with any one who would have insured me half the crop realized the preceding year from the same land and management. But the healing powers of nature and genial influences of summer suns and showers, in a few days restored the field again to a flourishing condition. A drought more severe than that of the preceding season followed in August; and our crop of corn per acre, was about 1-4 less than the crop of that year. My farmer, H. L. Gould, from his success with the mud which you analyzed, was strongly impressed with the belief that other peat mud would not prove as good. I requested him to make an experiment, which he accordingly did, with two cart loads of peat, such as makes good fuel, taken directly from the swamp, mixed with ashes, and used in the same quantity by measure, as the other compost. He planted with this four rows of corn through the piece. And, contrary to his expectations, if there was any difference, he acknowledged that these rows were better than the adjoining ones. The mud you analyzed, contained, you recollect, a large portion of granitic sand; this peat much less sand but more water, it being quite spongy. The same bulk, therefore, as taken from the meadow and used in our experiment would probably have weighed, when dry, not more than 1-3 or 1-4 as much as the other. The quantity of geine in the shovelful of the two kinds, varies not very much after all. I regret that Mr Gould did not repeat his experiments with the solution of geine last season. My farm is seven miles from my residence, and, like yourself I turn no furrows with my own hand, nor can I oversee in their various stages, experiments there. I suggest, advise, and leave him to execute. He found himself too much hurried with his work, to attend to this subject at the proper time. In answer to your question I say—that the solution the 2nd year was not applied to the same land, and although used in much larger quantities, it was not as strong as that used the past year.

Yours, respectfully,

ANDREW NICHOLS.

To S. L. Dana, M. D.

It will be observed that about three cords of swamp mud and 33 bushels of ashes, have been used per acre, in 1839, and 40 lbs. of potash in 1840.

The number of hills is 3630 per acre. Then calculating the real potash, there were given to each hill of corn, about 1-2 pint of ashes, or 32 grains of alkali in 1839, and 45 grains in 1840.

If three cords of swamp muck, were used in 1840, about 6 oz. of dry geine have been applied per hill—the muck being like pond mud. Now 45 grains of alkali and 6 oz, of geine, and $\frac{1}{7200}$ of a cord of pig manure per hill, have here produced effects equal to guano. No new source of nitrogen has been opened to the corn. The effects are due then, to the alkaline action on geine, and of salts upon silicates. The failure of the solution in the second year, is probably owing to the formation of sulphuretted hydrogen, see section (238).

No. III.—*Letter from Hon. Wm. Clark, Jr.*

NORTHAMPTON, 10th FEB'Y, 1842.

DEAR SIR:—

The results of the few trials I have made with alkalies to neutralize the acididity of swamp muck, have not been ascertained with that precision that is necessary to determine conclusively which is best. I will, however, give you the experiments (if they deserve the name,) as they were made, with the *apparent* results. The first was with fine well decomposed muck, from the swamp of which you had samples, numbered 5, 6, and 7. In the spring of 1840, 16 lbs. of soda-ash or white ash, dissolved in water, were carefully mixed with two estimated tons of the muck, and the mixture applied as a top dressing for corn. Two other estimated tons of the muck were served with eight bushels of dry wood ashes, all well mixed together and spread on one side of the muck that was served with the white ash, and further on, an equal quantity of fresh barn yard manure was spread, and still further on, an equal quantity of compost, made of one part barn manure, and two parts muck, mixed and fermented before using.

The land was a light sandy loam, on the border of a pine plain, and the whole field was treated alike in all respects, except the different kinds of manure, all of which was spread on the turned furrow, and harrowed in before planting. The corn planted where the wood ashes and muck were spread, early took precedence of all the other parcels, and continued apparently much the best through the season. Among the other parcels, no striking difference in growth or yield was manifest. The whole field was harvested together without separate weight or measurement; and the advantage which the ashes and muck apparently gave over the others, rests (where no experiment should rest,) on the opinion of those whose attention was called to it, while the corn was growing.

A similar trial of ashes and muck, and soda and muck, was made the same season on grass land; and the advantage was decidedly in favor of the soda-ash and muck, as on the corn land, it was in favor of the ashes and muck.

Why the soda-ash should act relatively, more favorably upon the muck spread on grass land, than when spread on corn land, I am unable to determine, unless it be the partial shade which the grass affords to protect it from the direct rays of the sun, and measurably preserve its moisture and softness. This inference is strengthened by the fact that muck, treated as in the above cases—with soda-ash in solution,(which makes it somewhat pasty,) in the only instance I have tried it—spread on the surface of an old field, without a protecting crop, or subsequent harrowings to cover it in the soil, became apparently sun baked so hard, as to defy, for a time at least, the softening action of water. This hardening effect was not observed to take place with the muck treated with the dry ashes, or in the manure compost, and may have arisen from the insufficient quantity of alkali used in the case mentioned.

In another case, one lb. of soda ash, and one lb. of soft soap, were mixed with four bushels of muck, and all put in a fifty gallon tub, and the tub filled with water, and left to stand five or six days, with an occasional stirring; at the end of that period, the dark coloured water was dipped off and applied to various garden plants and vegetables, and the tub again filled with water, and the muck stirred up, and after a day or two the water was again

dipped off and applied as before, and the tub again filled with water. This process was continued for two or three weeks in the early part of the season, and the muck, though gradually wasting, without additional alkali, continued to ferment from time to time, and yield black liquor, to appearance nearly as rich as at first. Rapid growth of the plants, followed in all cases when it was applied, and its effect upon a lot of onions, would have been ascertained with considerable accuracy, had not a "hired man," took it into his head that the few rows purposely left for comparison, were suffering by unwitting neglect, and gave them a "double dose," thereby equalizing the growth, and sacrificing the experiment to his honest notions of fair dealing, which required that all should be treated alike. In another case, a muck compost dressing, formed by previously slacking quicklime with a strong brine of common salt, to disengage the acid of the salt, that its soda might act on the muck when in contact, was applied as a top dressing for corn, without any perceptible effect, perhaps for want of skill in compounding.

Facts abundantly testify to the fertilizing properties of swamp muck and peat, when brought to a right state, and the subject of your enquiry, perhaps yields to no other, at the present time, in point of importance to our good old Commonwealth. Taking your estimate of the weight of fresh dug muck or peat, and Professor Hitchcock's estimate of the quantity in the state, and the saving of one cent per ton, in the expense of neutralizing its acidity, and fitting it for use in agriculture, when applied to all our swamp muck and peat, will amount to an aggregate saving to the industry of the Commonwealth, of over five and a half millions of dollars. Is there a reasonable doubt that more than ten times this one per cent per ton will be saved over any present process, when chemistry has shed its full light on the subject?

The magnitude and importance of a small saving in this matter, must certainly have been overlooked by some who have given advice on the subject of making muck compost. Respectfully,

Your most ob't serv't

WILLIAM CLARK, Jr.

S. L. Dana, M. D., Lowell. Mass.

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CORRECTIONS.

Page 99, seventh line from top, after word "plant," read "*wants not, they act.*"

" 108, fourth line from top, after "ammonia," read "*but.*"

" " fifth line from top, for "to be," read, "*is.*"

" 121, third line from top, for "17," read, "71."

" 142, read the 11th line, between the 8th and 9th.

At a meeting of the Board of Trustees of the Massachusetts Society for Promoting Agriculture, held 9th July, 1842:—

Voted, That Mr. Phinney be a committee, to ascertain the price of Dr. Dana's treatise on Manures, and report his opinion of the expediency, and the best mode of distributing this work for the interests of Agriculture.

At a subsequent meeting of the Trustees, on the 10th September, 1842, Mr. Phinney made a verbal report, commendatory of Dr. Dana's treatise, and it was—

Voted, That the Treasurer be authorized to purchase one hundred copies of Dr. Dana's treatise on Manures, for immediate distribution; and that Mr. Phinney, with the Secretary, be requested to take charge of the books, and of their distribution.

A copy from the records.

BENJAMIN GUILD,

Ast'nt Rec. Sec'y, of Mass. Soc. for Prom'g Agr.